S. HRG. 103-710

# NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM (NEHRP) REAUTHORIZATION



## HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

## COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED THIRD CONGRESS

SECOND SESSION

MAY 17, 1994

Printed for the use of the Committee on Commerce, Science, and Transportation



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# NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM (NEHRP) REAUTHORIZATION

TUESDAY, MAY 17, 1994

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY,
AND SPACE OF THE COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION,
*Washington, DC.*

The subcommittee met, pursuant to notice, at 2:45 p.m. in room SR–253, Russell Senate Office Building, Hon. John D. Rockefeller IV (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Elizabeth Inadomi, staff counsel, and Patrick H. Windham, senior professional staff member; and Louis C. Whitsett, minority staff counsel.

## OPENING STATEMENT OF SENATOR ROCKEFELLER

Senator ROCKEFELLER. This hearing will come to order.

Welcome to the subcommittee's hearing on the reauthorization of the National Earthquake Hazards Reduction Program, what we call NEHRP.

Like all of our programs this year, today the subcommittee will examine the link between Federal investment in research and technology and, on the other side, the benefits flowing to the American taxpayer from that research and technology.

This reauthorization hearing is especially timely because earthquake technologies developed under NEHRP played a significant role in mitigating damage during and after the major earthquake in Northridge in January of this year.

The Earthquake Hazards Reduction Act of 1977 established the Interagency Earthquake Program to help minimize the loss of property and life from earthquakes through scientific and engineering research. Saving lives is the primary goal of NEHRP, but the program also seeks to reduce earthquake damage and the related costs to that.

Clearly, the importance of NEHRP grows as the costs rise for restoring quake-damaged areas. For example, the Loma Prieta earthquake in October 1989 is estimated to have cost over $10 billion. The current estimates of Northridge are $15 billion.

When earthquakes are in the news, the Nation thinks of California. However, experts believe that 38 States face significant risk of earthquakes. While California currently may be the hardest hit, the States which are least prepared for earthquakes will sustain

much greater damage if they were to occur. That leads to the question of whether the technologies developed under NEHRP and proven to help mitigate damage are known, or more importantly are in use in all of the States at risk. That is a very important part of the discussion. Mr. Chairman, your comments, please.

## OPENING STATEMENT OF SENATOR HOLLINGS

The CHAIRMAN. The Subcommittee on Science, Technology, and Space is holding an important hearing today on the reauthorization of the National Earthquake Hazards Reduction Program. Since the last time the subcommittee held a NEHRP reauthorization hearing in April 1989, the Nation has been rocked by hundreds of minor earthquakes and several significant ones, most notably Loma Prieta in October 1989 and, more recently, Northridge in January 1994. Precious lives were lost in these earthquakes in addition to billions of dollars in property damage and lost income.

In the hearing 5 years ago, we focused on the issue of hazard mitigation. NEHRP, originally established in 1977 to predict earthquakes through scientific research, was refocused to create and apply technologies for hazard mitigation. Since that time, the Earthquake Program has developed technologies which have been used in retrofitting older bridges, highways, and buildings. Even with the unknown thrust-faults which apparently weave a complex web deep beneath the surface of Los Angeles, these technologies have reduced the potential for damage to the area's highly traveled freeways and interchanges.

Understanding earthquakes, like other natural disasters, is of great importance to the Nation, not only for the obvious public safety aspects but also the serious fiscal impacts. While the pressures of the Federal budget are more tighter than ever, Congress has provided over $9 billion in taxpayer dollars this year to help in restoring the quake-damaged area of southern California. It is estimated that another $6 billion will be provided through private insurers.

The potential costs of earthquake damage are even more alarming when considering that 38 of our States have significant risk of seismic activity. However, utilizing technologies proven to mitigate damage caused by earthquakes is purely voluntary, and we must consider retrofitting old building and bridges despite the expense of doing so.

In charting the course of the earthquake program for the next few years, perhaps the primary question should not focus on what hazard mitigation technologies the Earthquake Program is developing. Rather, the question should be how these technologies can reach the communities which are forecast to experience earthquakes. In doing so, the entire Nation stands to benefit from the research and technology efforts of this interagency Earthquake Program.

Thank you, Mr. Chairman.

Senator ROCKEFELLER. Thank you, Mr. Chairman. It is my hope that the witnesses before us today can answer that question. I also want to learn about the technology transfer efforts of the agencies represented on our panel and get recommendations to ensure that

the States are adopting earthquake mitigation technologies in their building codes and other relevant areas.

Also, the subcommittee will focus on the administration's fiscal 1995 budget request of $103.2 million for the earthquake program, which is a 3.6-percent increase from fiscal 1994, and compare this with authorizations of $102.7 billion in H.R. 3485, passed in the House before the President submitted his fiscal 1995 budget request to Congress.

This is the forum to discuss the strengths and the weaknesses of the earthquake program and a realistic course for the program to pursue for the next few years.

We are fortunate to have with us today all four Federal agencies participating in the earthquake program. We will have testimony from Mr. Richard Moore, Associate Director for Mitigation at FEMA, and he will be followed by the Hon. Gordon Eaton, Director of the U.S. Geological Survey, Dr. Joseph Bordogna, who is Assistant Director for Engineering at the National Science Foundation, and Dr. Richard Wright, Director of the Building and Fire Research Laboratory at NIST.

Senator ROCKEFELLER. At this time, I turn to my colleague from Montana, Senator Burns, the ranking member of the subcommittee, for any opening remarks.

## OPENING STATEMENT OF SENATOR BURNS

Senator BURNS. Well, Mr. Chairman, I do have a statement that I would ask that it be made a part of the record.

Montana ranks fourth, and we live in Montana on a couple of pretty major faults. I think our last major one was probably 1959. That was when we changed the Hebgen Lake and left some folks up there under the side of a mountain, about 30, 35 folks, something like that, and so we are interested in this issue.

Thank you for holding these hearings, and it will be interesting to hear their testimony, so I thank you very much.

[The prepared statement of Senator Burns follows:]

### PREPARED STATEMENT OF SENATOR BURNS

Mr. Chairman, I want to thank you for holding this hearing on the reauthorization of the National Earthquake Hazards Reduction Program. I have great interest in the Earthquake Program since Montana is one of six States considered to be at a "very high" risk of an earthquake. In fact, according to the Federal Emergency Management Agency, earthquakes pose the largest single-event natural hazard faced by the State.

The 6.6-magnitude earthquake in the Northridge, CA, area in January was a tragic reminder of the tremendous destructive force of an earthquake. In that earthquake, over 60 people were killed; over 1,000 people were hospitalized; and property damage exceeded $30 billion. Even today, months after that tragedy, tens of thousands of earthquake victims are still unable to return to their homes out of fear or safety reasons.

Most of the recent U.S. earthquakes have been in California so there is a tendency to see the earthquake hazards issue as an exclusively California problem. It is not. Earthquakes are a national problem. Thirty-nine States have a significant risk of earthquake activity. While, in recent times, the Central and Eastern States have escaped significant earthquake damage, the largest earthquake in the United States occurred, not in California, but in Missouri in 1812. Experts have indicated that the probability of a destructive earthquake in the Eastern or Central States by the year 2010 is at least 50 percent, and maybe much higher.

Mr. Chairman, no matter where an earthquake occurs, all of the Nation's taxpayers are affected because they pay for the billions in Federal assistance that are inevitably required to help people in the affected State or region.

We cannot prevent earthquakes. However, we can try to minimize the loss of life and property damage that they cause. That is why the Earthquake Program is so important. The program is aimed at assessing U.S. earthquake hazards and arriving at strategies to reduce their impact. This involves evaluating earthquake risks, developing more earthquake-resistant building designs, and strengthening the States' earthquake preparedness programs.

Indications are that we already are seeing the benefits of the program. While the 6.6-magnitude earthquake in Northridge caused about 60 fatalities, an earthquake of similar magnitude in Iran last year caused 55,000 deaths. The difference in death tolls is at least partially due to the activities supported by the Earthquake Program.

H.R. 3485 authorizes $308 million over 3 years for the four Federal agencies that operate the program: FEMA, NIST, NSF, and USGS. I note that the fiscal year 1994 authorization matches the fiscal year 1994 appropriation, and the out-year numbers reflect reasonable yearly increases for these activities. These levels should ensure a continuation of the important work being done in the program.

Mr. Chairman, I am looking forward to this hearing as an opportunity to examine some important issues regarding this program. For example, has coordination among the four NEHRP agencies improved? In the past, these agencies were said to have operated as four separate agencies rather than an integrated program. Also, I would like to know whether we are making practical use of the information and research produced by the program. Are architects and engineers and land-use planners taking into account input from the Earthquake Program in making their decisions? Finally, I would like to explore the vulnerability of my State of Montana to withstand a major earthquake and listen to your thoughts on our earthquake hazards mitigation efforts. Hopefully, our witnesses will have time to address these and related matters in their testimony today.

Thank you again, Mr. Chairman.

Senator ROCKEFELLER. OK. Thank you, Senator Burns, and Mr. Richard Moore, we will go to you, sir.

## STATEMENT OF RICHARD MOORE, ASSOCIATE DIRECTOR FOR MITIGATION, FEDERAL EMERGENCY MANAGEMENT AGENCY

Mr. MOORE. Thank you, Mr. Chairman. Mr. Chairman and Senator Burns, I am pleased to appear before you to testify in support of the National Earthquake Hazards Reduction Program for the Federal Emergency Management Agency. I serve as the Associate Director of FEMA for Mitigation. As you know, we cooperate with the other three partners who are sitting at the table in the administration and the development of that particular program.

I think that, clearly, the activity in California earlier this year has probably set the stage for this current review on the reauthorization, and has clearly demonstrated great need to continue the program that has been set in place by the Congress to focus in particular on the impact of mitigation to try to deal with those steps that we can take when an earthquake does occur.

FEMA has two major responsibilities under the NEHRP provisions. One is to work with State and local governments and with private sector groups and individuals to find ways to implement earthquake risk reduction, and the other is serving as a lead agency to work in cooperation with our partners to help coordinate and develop the program.

In the lead agency area we have several responsibilities. One is to look at the existing knowledge on the indirect economic consequences of catastrophic earthquakes, another is to look at the impediments to mitigation that exist and develop recommendations to minimize those impediments, a third is to coordinate the funding of post earthquake investigations and find ways to benefit from the lessons learned from those activities, and, finally, we have recently

provided staff support to an advisory committee that was authorized under the last NEHRP reauthorization act.

During the period of time that those events have occurred, we have, also managed activities along the programmatic side. Particularly, we have expanded our work with the States.

We have increased participation from 3 years ago when there were 17 States participating, to now having 33 States participating in the NEHRP program. We are working with them to help provide them with funding and technical assistance to provide transfer of the information that is developed through the program to their building code commissions, to their development agencies and others. In this way, they can benefit from what we learn as we coordinate the studies and also review what has happened when an event like Northridge occurs.

We have also worked with several consortia around the country. There are several groups of States that work together to help transfer the knowledge that is developed by research agencies and others to these various States and communicate that information. We support those several consortia that exist.

We have been working with the President's office in providing a report to the Congress that will be due in December on implementation of seismic safety standards in existing Federal buildings, as mandated by an act of the Congress, that would be similar to what we have had over the last couple of years for new Federal building construction.

We have also been working on efforts to strengthen the infrastructure and to work with States and localities to strengthen infrastructure from the vulnerability from earthquakes. We have also worked with the Department of Education to develop a strategic plan for program for earthquake education throughout the country.

There still is much to be done in dealing with earthquakes, as Northridge is teaching us. Much of it is in the area of mitigation. We clearly can continue to find new ways and through public awareness and information to help people, and encourage builders, engineers, and architects and others in the profession take steps—as they build buildings or as they reconstruct or repair buildings—to make people and property safer and less subject to harm when an earthquake does, as it will, occur.

Significant research has been done on the causes and effects of earthquakes, and we attempt to work with our partners in the NEHRP program to make that translatable to the average citizen, and particularly those in the building community.

The Federal Emergency Management Agency has also focused on three areas. One is the partnership that is involved in mitigation, working with States, localities, the private sector, to work together to make mitigation something that is understood and accepted and implemented across the country.

We are looking at currently developing a national mitigation strategy to find ways to package various Federal programs that will make them more effective. We are working in Kentucky and in California at the present time on a pilot project for tying our economic programs that the Federal Government supports to mitigation so that when we build a downtown area or an industrial park or whatever, it is more able to withstand seismic conditions, and

therefore the community, itself, becomes more sustainable under disaster conditions.

So, we are working on those sorts of activities by which we hope to make our country safer. We are continuing to learn, and we want to continue to work with this committee in strengthening the program.

[The prepared statement of Mr. Moore follows:]

PREPARED STATEMENT OF RICHARD T. MOORE

Mr. Chairman, Members of the Subcommittee, I'm extremely pleased to have this opportunity to appear before you and speak about the National Earthquake Hazards Reduction Program for the Federal Emergency Management Agency. My name is Richard T. Moore and I am the Agency's Associate Director for Mitigation.

FEMA collaborates in the NEHRP with the National Science Foundation, the U.S. Geological Survey, and the National Institute of Standards and Technology. I am honored to appear with them before you today. There should be no question in any one's mind about the effort each participating Agency has devoted to NEHRP. The advances in earthquake risk reduction in this country, and they are impressive, are due to this dedication by the NEHRP partners since Congress established the Program in 1977.

Mr. Chairman, the earthquake in Southern California on January 17th of this year has given us clear evidence, again, that if we want to address the earthquake risk in this country and minimize the disaster cost of earthquakes, we must do so by reducing that risk before the earthquake occurs by pre-event planning, research and mitigation.

It seems somewhat ironic that the last time the National Earthquake Hazards Reduction Program (NEHRP) underwent the reauthorization process, another major earthquake was fresh on everyone's mind. The Loma Prieta earthquake focused our attention on the effectiveness of this nation's earthquake mitigation program, and it resulted in Congress' passage of a reauthorization statute which provided needed crucial definition and refinement of NEHRP responsibilities, goals and objectives.

Under NEHRP, FEMA has two major responsibilities:

1) one is to work with State and local governments, with private sector groups, and with individuals, to implement earthquake risk reduction; and

2) the other is to serve as the lead Agency for the Program.

As you know, NEHRP is a multi-agency program involving all the Federal agencies here today: FEMA, the National Science Foundation, the U.S. Geological Survey and the National Institute of Standards and Technology. Each of the Agencies will speak to you about their contributions to understanding earthquakes. Therefore, I will concentrate my remarks on FEMA's activities under NEHRP, our work since the 1990 reauthorization, and our view of the future directions for NEHRP.

The NEHRP Reauthorization Act of 1990 placed significant challenges before FEMA. But most importantly, the fulfillment of those challenges has made clear to FEMA the path we must follow in our future work under NEHRP. Let me spend just a few moments on the specifics of those challenges.

In the lead Agency arena, the 1990 Reauthorization presented FEMA with some very challenging responsibilities:

- using a panel of experts, we looked at the existing knowledge on the indirect economic consequences of catastrophic earthquakes;
- another panel of experts examined the impediments to mitigation implementation and formulated recommendations on how implementation could be improved;
- a review of the funding of post earthquake investigations was conducted and recommendations for the future were presented;
- we provided staff support to a Program Advisory Committee and the conduct of its meetings; and
- we continued the preparation, in coordination with the other NEHRP Agencies, of Program plans, reports and budgets.

I am happy to report that these were all accomplished. We also undertook other activities under our lead role in expanding the recognition of NEHRP among a variety of target audiences, supported activities to increase the participation in NEHRP, and developed campaigns and outreach activities for the small business community to enhance their involvement in earthquake risk education in collaboration with the local governments.

Mr. Chairman, each of these activities has underscored for FEMA the importance of reducing our losses before earthquakes occur.

As I noted earlier, FEMA also has programmatic responsibilities. On the programmatic side, and in response to the 1990 Reauthorization:

- FEMA conducted an expansion of our efforts to fund States and assist them in their efforts to reduce their earthquake risk. The number of participating States has increased from 17 to 33. We have put into place improved technical assistance delivery systems to supplement their ability and capacity in the earthquake risk reduction field.
- We have continued our fiscal and technical support of regional earthquake consortia. The Central U.S. Earthquake Consortium, who we have been honored to work with and fund since their establishment in 1983, is an example of the positive effects such organizations can have;
- We have monitored and reported on Executive Branch implementation of the President's order on seismic safety in new Federal buildings. We have provided reports on these activities to the President and to Congress;
- We have funded and worked with the Interagency Seismic Safety Committee in Construction to help in the development of a programmatic strategy and approach for addressing the problem of existing hazardous federal buildings;
- We have examined the vulnerability of the infrastructure of the Nation to earthquakes and reported on its economic impacts to the country should an earthquake occur;
- We have worked with the Department of Education and others in the development of a strategic plan for our Nation's earthquake education efforts; and
- We have developed techniques that assist State and local governments in their conduct of earthquake risk reduction. These include training courses, exercises, educational materials, workshops, and the like.

Despite all the work FEMA has done in these areas and in fulfilling the critical requirements of the 1990 reauthorization act, there is still much to be done. Mr. Chairman, all these accomplishments, and all the work they represent, have repeatedly served to underscore one simple fact—we must do more to achieve an acceptable level of earthquake risk mitigation in this country.

The importance of implementing mitigation is a lesson of the earthquakes we have experienced. It is a conclusion of the studies and reports that have been generated by expert panels and the NEHRP Advisory Committee, and it is the foundation of the emergency management system FEMA seeks to establish in the U.S. FEMA will strengthen, deepen and cultivate the implementation of earthquake risk reduction in the U.S. using the delivery mechanisms we have developed over the years under our NEHRP authority:

- We will work with State and local governments across the U.S. on the adoption and enforcement of seismic safety codes for new buildings;
- We will work with State and local governments to reduce the exposure to loss of their existing infrastructure;
- We will continue to work with the academic and private sectors to make "state-of-the-practice" the same as "state-of-the-art"; and
- We will continue and enhance our efforts to communicate simple and economical mitigation techniques to small businesses, schools, hospitals, utilities, families and individuals.

Mr. Chairman, FEMA wants to apply the post-event lessons of Northridge to improve our existing pre-event delivery systems; to apply the principles of effective mitigation implementation which we have learned over the years:

- *Partnership*—The implementation of earthquake mitigation, indeed of any natural hazards risk mitigation, relies on every sector of today's society—State and local governments, businesses, industries, building professions, and individuals. We need this help to develop the best techniques, and we must help them implement those techniques;
- *Packaging*—There are an enormous number of programs throughout the Nation which deliver needed federal assistance and backing to community development, to the construction of our infrastructure and our buildings, and to the implementation of risk reduction. We must package those systems together so that they do not conflict one with another, and so that communities have reasonable flexibility in the appropriate level of mitigation they set as their goal; and
- *Incentives*—We have learned in virtually every natural hazards program, in virtually every natural hazards experience, and from virtually every expert with whom we discuss the impediments to implementing mitigation—without some real incentives, America will never achieve the level of earthquake risk reduction in this country that you and our fellow citizens have a right to expect.

The Federal Agencies of the NEHRP, and all the partners with whom we work around the country, have made great strides toward understanding the causes and effects of earthquakes. We have developed mitigation techniques that work, and

that are accepted by practitioners as useful. We have developed delivery mechanisms—training courses, educational tools, exercises, public awareness materials and campaigns, technical assistance, and many others.

Within the current management structure of the NEHRP, we have developed a level of coordination which, I believe, is unmatched elsewhere. But in order to reach the level of risk reduction the Congress, the people of the U.S., and indeed the NEHRP Agencies themselves, have a right to expect, we must focus our attention, our resources, and our authorities on achieving that mitigation. FEMA intends to do just that. We do not want to wait until the next Loma Prieta, the next Northridge, the next New Madrid, or the next Anchorage, Alaska earthquake and see how fast we can pick up the pieces. We want to have fewer pieces to pick up.

Mr. Chairman, that concludes my remarks for this morning. will be pleased to answer any question you or other members may have.

Senator ROCKEFELLER. Mr. Moore, I thank you.

## STATEMENT OF DR. GORDON EATON, DIRECTOR, UNITED STATES GEOLOGICAL SURVEY; ACCOMPANIED BY DR. ROBERT L. WESSON

Dr. EATON. Thank you, Mr. Chairman. The Geological Survey fully supports H.R. 3485, the reauthorization bill for the National Earthquake Hazards Reduction Program, and we look forward very much to participating in the comprehensive review that has been proposed by Congressman Brown and his colleagues from the House side.

The USGS strongly supports a proactive NEHRP program and is working with the other program agencies represented here at the table to strengthen its effectiveness. We must increase mitigation and pursue new applications for ongoing research. At the same time, we must continue to develop a strong research base to better understand where earthquakes will occur, why they occur, how big they can be, and what effects they will generate, and the impacts these effects might have on human structures.

Based on the seriousness of an earthquake hazard for a given region in this country and the population density and the economic infrastructure at risk in the area, the Geological Survey has placed high priority on studies in four earthquake-prone regions: southern California, the site of the Northridge earthquake of this past January, the San Francisco Bay area, the Pacific Northwest, and the Central United States.

We have geologists on the ground in these areas, each of them working with State and local preparedness agencies. The principal threat from earthquakes is the possible collapse of buildings and lifeline systems that are inadequately designed or built to resist earthquakes.

In response to NEHRP, postearthquake investigations are being carried out to document, to understand, and to explain what happened so that we can reduce the losses from future earthquakes. Of key interest has been the widespread nature of strong ground motion and its relationship to the failure of lifelines and buildings. Through a cooperative agreement with the Applied Technology Council, the USGS has sponsored five very well-attended regional workshops to pass new technologies and applied research results produced by the survey on to practicing engineers in these areas.

Immediately after the Northridge earthquake earlier this year, USGS personnel and cooperators monitored aftershock activity together, analyzed strong motion seismograms, and characterized the

type and extent of the damage in the area. All four NEHRP agencies, those represented at this table, in cooperation with State and academic teams from area universities, gathered perishable information about previously unknown faults in the area, ground breakage, and structural damage. They also investigated permanent ground deformation that took place in the area.

As a followup on the Landers/Big Bear and Northridge earthquakes, both of them southern California earthquakes, USGS scientists and their colleagues are reevaluating the probability of major earthquakes in southern California.

NEHRP-generated information continues to stimulate investment in risk reduction measures. For example, a recent technical report indicated a 2-in-3 chance of at least one magnitude 7 earthquake in the San Francisco Bay area during the next 30 years.

In response to that report, the Geological Survey, with the sponsorship of several agencies, prepared a newspaper insert printed in English, Spanish, Chinese, and braille, that explained what concerned citizens could do in the event of an earthquake.

In combination with information from other sources, this report spurred significant personal mitigation and preparedness action. Private corporations are now investing hundreds of millions of dollars to strengthen their vulnerable structures in San Francisco and Oakland, CA.

Geologic studies of coastal tidal flats indicate that infrequent but nevertheless great earthquakes have occurred before on the Washington, Oregon, and northern California coasts, and in response to this new realization, Washington and Oregon have recently proposed revisions to building codes in the potentially impacted counties.

Examples of risk reduction measures spurred by NEHRP and its program are not limited to the Western United States, however. In the Central United States, recent geologic studies have identified the occurrence in prehistoric times of a major earthquake in the Wabash River Valley in Indiana.

When considered in conjunction with the large Mississippi earthquakes of 1811 and 1812, probably the largest magnitude earthquakes that have taken place in the United States in the time of European habitation here, this increases the size of the region known to be capable of generating very damaging earthquakes in the Central United States.

Although the annual probability of a damaging earthquake in this region is low, it is vulnerable because of a very high-population density, because of unreinforced masonry buildings, and because of risk management policies that vary a great deal from State to State and many of which are inadequate.

Through USGS-assisted workshops, the Central U.S. Earthquake Consortium has made progress in the increasing hazard awareness in the region. By and large, Americans' understanding of earthquakes varies widely at the present time. The hazard awareness is improving.

The capacity to build earthquake-resistant buildings and lifelines in earthquake-prone regions also varies widely, but it is likewise improving. Additional gains will be made as the state of scientific

understanding of earthquake threats is increased and the quality and effectiveness of risk reduction measures are enhanced.

Working with our three NEHRP partners, we have established a 1–800 number to respond to what we anticipate to be thousands of requests for information that we think will follow a major televised special on earthquake disaster preparedness that is going to be aired by ABC on Saturday evening this week.

Although we can point to major gains that have occurred as a direct result of the NEHRP program in the past 3 years, there is still much to be accomplished. We look forward to a significant continued role in accomplishments in this important national program.

Mr. Chairman, that completes my statement, and I will be happy to remain at this table and answer questions.

[The prepared statement of Dr. Eaton follows:]

PREPARED STATEMENT OF DR. GORDON EATON

Mr. Chairman and members of the Subcommittee, I thank you for the opportunity to appear before you on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) and the role that the U.S. Geological Survey (USGS) is serving in the NEHRP Program.

We support reauthorization of the programs in H.R. 3485 at the levels requested in the President's Budget. We understand that the office of the U.S. Trade Representatives is reviewing section 2 of the bill, the "Buy America Provisions." We look forward to participating in the high-level, comprehensive Executive Branch review of the NEHRP proposed by Congressman Brown and his colleagues and to contributing to the development of a strategic plan that will ensure the operation of a unified program.

Earthquakes are one of the most devastating natural hazards and pose a severe threat to life and property in many regions of our Nation and around the world. Since the Geological Survey last met with this Subcommittee, 234 damaging earthquakes worldwide with magnitudes greater than 6.0 have increased the number of cumulative fatalities during this century to 1.543 million. Of these 234 earthquakes, 64 have affected various regions in the United States, causing loss of life, injuries and damage to property. There have been 21 earthquakes with magnitudes greater than 5.0 which have affected areas in the Pacific Northwest, southern California, Nevada, and Utah. The magnitude 6.8 Northridge earthquake which struck southern California on January 17, 1994, damaged over 40,000 structures and caused 57 fatalities and $13 to 20 billion in damage. On September 20 and 23, 1993, respectively, magnitudes 5.9 and 6.0 earthquakes occurred near Klamath Falls, Oregon. They are the largest to have occurred in Oregon in this century. There were three fatalities and damage costs of approximately $7.6 million. Hawaii and portions of Utah, Wyoming, and Idaho have experienced earthquakes of magnitudes greater than 5.5 in the past several months. The Landers, Mendocino, and Portland earthquakes which struck California and 9regon in 1992 caused approximately $158 million in damage and 500 injuries. A magnitude 8.1 earthquake struck Guam in August.

Our Nation has a fundamental responsibility and self-interest in reducing earthquake risk. As a part of this responsibility, the USGS endorses the need of increasing mitigation and pursuing new applications for on-going research. At the same time, we must continue to develop a strong research base for a better understanding of where earthquakes will occur, why they occur, how big they can be, and to learn more about the effects that they will generate. Basic research and monitoring have contributed key components to our Nation's improved mitigation capacity and ability to apply research results and information for informed decision-making. Poor scientific knowledge permits poor decisions; whereas, sound scientific knowledge substantially improves the likelihood of good decisions.

The principal threat to humankind from earthquakes is the possible collapse of buildings and lifeline systems that are inadequately designed or constructed to resist ground shaking or earthquake-induced ground failure. Earthquakes can also result in damaging tsunami (seismic sea waves) and permanent changes in sea level elevation relative to land in coastal areas, which occurred, for example, as a result of the Mendocino and the Nicaragua earthquakes last year. In addition, earthquakes present a hazard when they rupture the surface of the Earth. The Landers

earthquake in 1992 created a zone of surface ruptures—some with horizontal displacements of up to 20 feet—extending a distance of 50 miles in southern California.

The National Earthquake Hazards Reduction Program addresses these issues and others. It has made significant progress on many fronts since its establishment in 1977. For example:

- Deeply buried "blind" thrust faults have been identified as a significant source of seismic hazards in a number of locations in southern California. The 1994 Northridge earthquake occurred on one segment of an extensive system of "blind" thrust faults in urban southern California. A thrust fault is a low angle fault with a dip of less than 450. Along this kind of fault, the upper block, called the hanging-wall block, has moved upward relative to the lower block. Regional, compressive forces push the blocks together.
- Significant advances have been achieved in forecasting the occurrence of future damaging earthquakes and in describing and characterizing the ground motions and ground failure these events are likely to generate.
- New knowledge about earthquake ground motions and the response of buildings to strong motion has been used to formulate provisions for the design and construction of earthquake-resistant buildings; these provisions have been adopted as part of national model building codes.
- Key factors leading to improved assessments of earthquakes have been developed by NEHRP. These factors include a comprehensive knowledge base which has contributed to improved mitigation, preparedness, and emergency response. Additional benefits include transfer of information and technology to end users to directly impact societal needs related to recovery and retrofitting and reconstruction of structures (buildings, lifelines and transportation corridors).
- Partnerships, collaboration and technology transfer activities have been strengthened among private and public organizations throughout the Nation for research, development, and application of fundamental knowledge to improve policies and professional practices.

The DOI and the USGS strongly support a proactive and effective NEHRP and are working with the other NEHRP agencies and the Congress to strengthen the coordination and effectiveness of this unique program. We are strongly committed to a multi-agency NEHRP and to accelerating the reduction of earthquake risk throughout the Nation. For over a decade, the USGS, in cooperation with the Federal Emergency Management Agency (FEMA), National Institute of Standards and Technology (NIST), and the National Science Foundation (NSF), has conducted multidisciplinary studies to provide our Nation with an accurate understanding of the causes and effects of earthquakes. We are working together with the four principal NEHRP agencies to foster earthquake risk management throughout the United States.

Significant new insights and techniques for assessing future earthquake potential have emerged from NEHRP and include new probabilistic techniques to combine data from a variety of observations to make forecasts of future earthquakes. Significant advances have also been achieved in describing and characterizing ground motions expected to be generated in future events. And microzonation techniques, the estimate of local site variations in earthquake effects, are being developed under the Hazards Mapping Act (California Assembly Bill 3897) for future implementation in California.

## NEHRP COORDINATION EFFORTS

In response to the previous NEHRP reauthorization, a new, multiagency subcommittee was created to develop a plan for post-earthquake investigations. Chaired by the USGS, the program of post-earthquake investigations is organized to take advantage of the opportunity to use worldwide damaging earthquakes as a scientific laboratory. The goal of NEHRP post-earthquake investigations is to document, understand, and explain what happened in each damaging earthquake to develop a knowledge base that can be used to reduce losses from and evaluate the probability of future earthquakes. All four NEHRP agencies described above have roles in conducting or supporting post-earthquake investigations. Ten earthquakes were investigated in 1992-1994: Northridge, Klamath Falls, Mendocino, Landers-Big Bear, Portland, Guam, Erzincan (Turkey), Cairo (Egypt), Managua, and Sea of Japan. Each produced valuable information. As a follow-on to the Landers-Big Bear earthquakes, and most recently to the Northridge earthquake, USGS scientists-and their colleagues to are reevaluating the probability of major earthquakes in southern California.

Immediately after the Northridge earthquake, USGS personnel and cooperators responded to monitor aftershock activity, coordinate with and provide information

to local and Federal emergency officials, analyze strong motion seismograms, characterize the type and extent of damage, and determine specific features of the mainshock. The four NEHRP agencies, in cooperation with State and university teams, gathered perishable information about previously unknown faults, ground breakage and structural damage, and permanent ground deformation through deployment of portable instruments. Of key interest has been the widespread nature of strong ground motion and its relationship to the failure of lifelines and buildings.

The FY 1994 emergency supplemental appropriation provided funds for follow-up studies to the San Fernando Valley earthquake. Funds have been distributed by FEMA to the USGS, NSF and NIST. The highest priority USGS tasks will be addressed either through the four-agency program announcement, or through internal USGS efforts funded with the $4.0M coming to the USGS from the $15.0M appropriated to FEMA. The highest priority tasks are:

1) Studying the hazard environment (assessing the earthquake source; assessing the influence of geologic structures; and combining earth science information Into products such as local site response maps that show variations in expected ground motion)

2) Studying the built environment (siting and geotechnical engineering; building and structures; urban infrastructure systems—lifelines; and risk and damage assessments)

A new facility—the Southern California Earthquake Center (SCEC)—has been created to address the earthquake hazard in southern California. SCEC, a consortium of seven research institutions in partnership with the USGS and NSF, was established in 1991 to improve forecasts of damaging earthquakes and their effects through multidisciplinary earth science research. A fundamental goal of SCEC is to develop a master model that will provide the basis for a time-dependent probabilistic seismic hazard analysis of southern California.

Response of NEHRP agencies to the powerful earthquake which struck Japan on July 12, 1993, is another recent example of a highly successful cooperative postearthquake investigation. Under the auspices of the U.S.-Japan panel on Wind and Seismic effects, NIST coordinated the effort with a number of other organizations including the Earthquake Engineering Research Institute (EERI), NSF, FEMA, Forest Products Laboratory, the USGS and NOAA. A team of 12 from the U.S. worked closely with a team of about 10 from Japan to gather information about the geological, seismological structural, geotechnical, fire, and tsunami effects.

The objectives of these investigations are to:

—assemble and set priorities on problems which can be addressed by studying such earthquakes

—acquire and analyze time sensitive or perishable information to establish a knowledge base and to learn as much as possible from the physical and social aspects of the tragedy which cannot be duplicated in the research lab or on a computer

—accelerate acquisition of fundamental knowledge on the earth science, engineering and sociology of earthquake risk management

—increase the awareness of policy makers on the earthquake hazard and their options for risk management

—transfer technology to and from all regions of the Nation and other countries to increase the capacity to adopt and implement earthquake risk management policies and professional practices

—promote realistic change through scientifically based expansion of risk management and policies throughout the U.S.

Refocus of emphasis on regional needs:

The USGS has reshaped its management and operational structure to accelerate progress toward the USGS NEHRP goals. In 1990, the USGS, with participation of its NEHRP partners, conducted a major strategic planning effort for its part of the NEHRP program. The resulting strategic plan, "Goals, Opportunities and Priorities for the USGS Earthquake Hazards Reduction Program" defines four goals for the USGS component of NEHRP, proceeding from basic scientific investigations to implementation of research results. The fourth goal, "Using research results" is a strong commitment to foster the implementation of research in mitigation, preparedness, and emergency response programs.

Also, the USGS has placed high priority on studies in four earthquake-prone regions: the Pacific Northwest (including Washington, Oregon and Alaska), the San Francisco Bay area, southern California, and the central U.S. (impacted by 4 great earthquakes in 1811-1812). To determine where to focus USGS efforts, we looked at two fundamental criteria:

- the seriousness of the earthquake hazard for a given region and
- the population density and the investment in economic infrastructure at risk in that region.

For each region, the USGS has appointed an on-site coordinator, who is charged with identifying the needs of end users in the region and developing a comprehensive program to meet these needs. In addition, the USGS continues to support work in other geographic areas of high to moderate seismic risk such as the Wasatch fault zone of Utah, the southeast, northeast and Hawaii.

Since the USGS last appeared before this committee, NEHRP-generated information continues to stimulate the private sector to invest in-risk reduction measures. In 1990, the USGS Circular 1053, "Probabilities of Large Earthquakes in the San Francisco Bay Area, California," presented a consensus view of earth scientists that there was a two-in-three chance of at least one magnitude 7 earthquake in the Bay area during the next 30 years. The message of this technical report was interpreted for the general public in the USGS-prepared, but multi-agency jointly sponsored, newspaper insert "The Next Big Earthquake—Are You Prepared?" The insert, which was published in English, Spanish, Chinese and Braille and distributed to 2.4 million homes, also explained what concerned citizens could do to reduce the likelihood of being injured or killed in an earthquake. These complementary reports, in combination with reinforcing information from other sources, spurred significant personal mitigation and preparedness actions. Private corporations are now investing hundreds of millions of dollars to strengthen their vulnerable structures in San Francisco and Oakland. Utilities are investing to repair and strengthen underground pipelines throughout the Nation. This finding, based on social science research, is corroborated by a practicing structural engineer from San Francisco. He states that his clients now recognize seismic safety as a key objective in the design of new or the retrofitting of existing structures, whereas before they generally were reluctant to accept the added expense to assure seismic safety.

NEHRP COORDINATION ACCOMPLISHMENTS

The USGS, with FEMA participation, has organized a group of Federal, State, and local agencies and private sector organizations, which is planning workshops on earthquake-generated landslides in the San Francisco Bay region and on the future of Geographic Information Systems (GIS) in transmitting earth science information. The group is called the Coordinating Organization for Northern California Earthquake Research and Technology (CONCERT). The USGS, through a cooperative agreement with the Applied Technology Council, has sponsored five extremely successful, well-attended regional workshops to enhance constructive dialogue between USGS earthquake scientists and practicing engineers. The objectives are to ensure that new technologies and applied research results produced by the USGS are transferred effectively and promptly to the engineering community.

External grants supported by NEHRP have resulted in authoritative documents containing earthquake mitigation information aimed at all elements of the general public and, especially local planners in Utah and in northern California. The Utah publications include a brochure ("A Guide to Redressing Losses from Future Earthquakes in Utah—Consensus Document") and a book ("Expert Synthesis and Translation of Earthquake Hazard Results—A Book for non-Scientists in the Wasatch Front Region"). The California publication ("On Shaky Ground"), stimulated by the Mendocino earthquake in 1992, is a newspaper insert addressed specifically to residents of the North Coast who need guidance on how to deal with their particular risks for preparedness.

Great progress has been made in improving our understanding of risk in the Pacific Northwest. Geologic studies of tidal flats of the coastline indicate that infrequent, great earthquakes have occurred before on the Washington, Oregon, and Northern California coasts. In response to this new realization, Washington and Oregon have recently proposed revisions to building codes in many potentially impacted counties. A recent annual meeting of the Earthquake Engineering Research Institute. in Seattle, devoted two sessions to discussion of risk-reduction measures in response to the new discoveries coming from these NEHRP-sponsored investigations.

Examples of risk-reduction measures spurred by NEHRP-generated knowledge are not limited to the western states. The USGS and FEMA are currently collaborating to support reaching a consensus on the earthquake potential in the New England states. A regional conference is being planned for this winter.

In the Central United States, recent geologic studies have led to the identification and delineation of a large prehistoric magnitude earthquake in the Wabash Valley. The recognition of this event in an area adjacent to which the large earthquakes occurred in 1811-12, increases the size of the region now known to be capable of generating damaging earthquakes and strong ground-motion. Although the annual probability of a damaging earthquake is low, the region is vulnerable because of

high population density, a large number of old, hazardous, unreinforced masonry buildings, and risk management policies that vary from state to state. The Central United States Earthquake Consortium (CUSEC), which represents 15 States, has made good progress in increasing hazard awareness in the regions through USGS-assisted workshops, but much more needs to be done to change risk management policy and practices. CUSEC has formed working partnerships with the USGS and State geological surveys and has encouraged involvement of universities and private sector companies in the region.

In response to this Subcommittee's 1990 amendments to the National Earthquake Hazards Reduction Act, the USGS has established, using existing facilities, a Center for the International Exchange of Earthquake Information. The USGS' National Earthquake Information Center (NEIC) in Golden, Colorado has assumed responsibility for this function.

Recent damaging earthquakes are a reminder of continuing hazard. The USGS is continually making strides to improve our understanding of the earthquake risk throughout the United States. We do know many of the characteristics of earthquakes that have affected particular geographic regions in the past. decent experience and our current level of knowledge indicate that California is exposed to the most eminent earthquake threat of any of our contiguous States. A recent progress report ("Future Seismic Hazards in Southern California, Phase I: Implications of the 1992 Landers Earthquake sequence") concluded that the yearly probability of a magnitude 7 or larger earthquake has increased as a result of the Landers earthquake sequence. This report, aimed at disaster-preparedness personnel, science writers, the public and the earth science community, represents development of consensus about contemporary hazard in southern California and was prepared by individuals representing the National Earthquake Prediction council (NEPEC), the California Earthquake Prediction Council (CEPEC), and the Southern California Earthquake Center (SCEC). A second report to be published in the next several months will quantitatively address the more difficult problems identified in Phase I and will consider in more detail additional faults and earthquake probabilities in the broader southern California region.

Other regions which have a high earthquake hazard are Alaska, Hawaii and the Puerto Rico-Virgin Islands region. The states of the Pacific Northwest, the Central United States, and the Northeast have historically experienced major earthquakes but the knowledge base is incomplete for these regions in terms of answering the questions: where, how big, and when.

The understanding of earthquakes by the Nation's populace of 250 million varies widely at present, but hazard awareness of the public is improving. The capacity to construct earthquake resistant buildings and lifelines in earthquake-prone regions varies greatly from state to state, or even from one local jurisdiction to another, but it is also improving. Additional gains will be made as the state of scientific understanding of the local earthquake threat and the quality and effectiveness of risk reduction measures being taken locally are increased.

Each damaging earthquake is a reminder that we still have a great deal to learn. In conclusion, the USGS values the guidance and suggestions of this Subcommittee as to how we can better serve the needs of the Nation. Although we can point to major gains that have occurred as a direct result of the NEHRP in the past three years, there is still much to be accomplished; and, we look forward to a significant continued role and accomplishments in this very important National program.

Senator ROCKEFELLER. Thank you very much, Dr. Eaton. Dr. Bordogna.

## STATEMENT OF DR. JOSEPH BORDOGNA, ASSISTANT DIRECTOR FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. BORDOGNA. Mr. Chairman, Senator Burns, NSF is pleased to be one of the principal agencies in the National Earthquake Hazard Reduction Program. Participating in the program is consistent with our policy of integrating NSF's activities with those of other agencies when it is in the best interests of the nation. NEHRP has taken significant steps, in cooperation with local and State organizations, in meeting the challenges posed by earthquake hazards, and we are happy that NSF has been a full partner in this effort.

Since its founding, NSF's mission has remained focused on its charge, to support science and engineering research and education,

to advance national health, prosperity, and welfare. We focus on research and education as synergistic investments and as integral inseparable components of our mission. This leads to federally funded research which has identifiable economic and social benefits, as well as representing excellence in science and engineering per se.

Earthquake research activities are supported at NSF in both the geosciences and the engineering directorates. Fundamental scientific earthquake research is supported in the geosciences directorate, while the engineering directorate funds earthquake engineering research and socioeconomic studies on earthquake hazard mitigation and preparedness. Significant progress is being made through these programs in understanding plate tectonics and earthquake processes, geotechnical and structural engineering, and the societal impacts of earthquakes.

NSF has attempted to further the advance of knowledge on earthquake hazards and techniques for coping with them by enabling talented individual investigators, as well as engineering teams in centers, to conduct both research fundamental to the engineering process and research focused on a specific need.

The two centers that we are currently supporting which focus on earthquake hazards are the National Center for Earthquake Engineering Research and the southern California Earthquake Center, the latter funded in collaboration with USGS. To further the deployment and utilization of research results, NSF is also involved in significant dissemination and education activities, including publications, on line data centers, computer networks, the education and training of the next generation of researchers and practitioners, and information clearinghouses. Although much remains to be done and technology deployment is a continuous process, work supported by NSF is reaching and being used by many professional designers, planners, and emergency managers in areas at risk to earthquakes.

One way of looking at the earthquake hazard across the country is to view it as a problem separate from and unrelated to other challenges facing the Nation. However, we feel that this is shortsighted and that the best approach to finding solutions to this problem is to see it in broader systems terms and thus confront it at the same time that related problems are being dealt with, maximizing limited resources in the process.

For this reason, NSF sees the seismic threat in the context of badly needed improvements in the Nation's civil infrastructure generally which, if not properly addressed, could result in continued deterioration in our quality of life and impairment in our ability to compete economically in the global marketplace.

We expect that the earthquake research programs at NSF will contribute to a new research initiative we are undertaking, entitled "Civil Infrastructure Systems," by focusing on such topics as vulnerability assessment technologies, retrofit repair and replacement techniques, smart materials and advanced structural systems, and intelligent control systems.

Let me conclude with a few comments about NSF's involvement in the investigations following the January 17, 1994 Northridge earthquake. Like NSF-sponsored postearthquake investigations in

the past, our activities have been closely coordinated with those being carried out by the other NEHRP agencies.

Immediately after the earthquake, interdisciplinary teams sponsored by NSF moved to the earthquake site to conduct postdisaster audits and to collect perishable data on strong ground motions, impacts on buildings and civil infrastructure systems generally, and social and economic effects. At the same time, the NEHRP agencies met on a regular basis to develop plans to carry out a long-term program of research made possible by a $15 million special appropriation from the Congress.

A coordinated program of research, information dissemination, and mitigation activities will be carried out internally by FEMA, USGS, and NIST. An external research program will be carried out through NSF in partnership with the other NEHRP agencies, focusing on learning lessons from the Northridge earthquake on the hazard environment, the built environment, and socioeconomic impacts. These cooperative NHERP activities offer the promise of major advances in earthquake hazard mitigation in the Nation.

Senator ROCKEFELLER. I am sorry. I did not understand your distinction between internal and external. They both sounded the same to me.

Dr. BORDOGNA. The external research program solicits proposals from the external community which we merit review and fund, and the internal research program is conducted inside the agencies.

Senator ROCKEFELLER. I see.

Dr. BORDOGNA. NSF does not do research itself, it supports it. That is one major difference between external and internal.

We at NSF look forward to our continued cooperation with FEMA, USGS, and NIST under the NEHRP banner as we work to achieve, in partnership with local, State, private sector groups, and other Federal agencies, the national goal of increased earthquake hazard reduction.

That completes my testimony.

[The prepared statement of Dr. Bordogna follows:]

PREPARED STATEMENT OF DR. JOSEPH BORDOGNA

Thank you for giving the National Science Foundation the opportunity to testify today on the reauthorization of the National Earthquake Hazards Reduction Act, which established the National Earthquake Hazards Reduction Program (NEHRP) in 1977. NSF is very pleased to be one of the principal agencies in NEHRP. Participating in the program is consistent with our policy of integrating NSF's activities with those of other agencies when it will facilitate the achievement of national goals, which in the case of NEHRP is the reduction of deaths, injuries and property damage caused by earthquakes. We feel that NEHRP, in cooperation with other Federal agencies and local and State organizations throughout the country, has taken significant steps toward meeting this challenge and we are pleased that NSF has been a full partner in this effort.

As you realize, the U.S. is one of many countries around the world that lives with the threat of earthquakes. And even though much remains to be done by NEHRP in helping to make our nation safer from this threat, much has been accomplished by the program. Recognition of our relative progress in countering earthquake hazards comes from the many countries that look to us for leadership and who are eager to join NSF and the other NEHRP agencies in cooperative activities.

It is a major challenge for NSF and the other NEHRP agencies to develop cooperative efforts to improve seismic safety in the built environment. The existing stock of buildings and lifelines have a estimated replacement value in excess of $20 trillion, or 20,000 times the 1994 NEHRP budget, which annually approaches $100 million. This makes it imperative that NEHRP concentrates on those types of research,

education, code analysis and other activities that can provide the basis for cost-effective hazard reduction in the built environment.

To put our involvement in NEHRP in context, I would like to begin with some remarks about the NSF mission. Then I will discuss specifically the role of NSF in NEHRP.

In recent years the pace of change in science and engineering, along with the pace of change in domestic and world affairs, has been startling. Yet NSF's mission has remained consistently relevant and true to its charge: to support science and engineering research and education in order to advance national health, prosperity, and welfare.

At NSF, we focus on research and education as synergistic investments and as integral, inseparable components of our mission. Federally funded research can and should have identifiable economic and social benefits, as well as represent excellence in science and engineering.

The strategy we are pursuing at NSF aims to continue the nation's tradition of excellence across the frontiers of scientific and engineering knowledge. And in partnership with other Federal entities, we seek to enhance the societal return on investments in scientific and engineering research made by the Federal government through NSF.

We place great emphasis on the context in which the research occurs—contexts that are relevant to national goals in such areas as education, environmental sustainability, and the creation of reliable and safe civil infrastructure systems. This approach demands a more global understanding of the process of scientific discovery, an appreciation for how it relies on the diffusion of knowledge, and an awareness of how both of these are related to technological innovation. It gives us an opportunity (and an obligation) to build a stronger connection between the Federal investment in R&D and eventual benefits for the public good.

NSF supports research in many disciplines, and this is reflected in the role we are assigned in NEHRP and the expectations of Congress as reflected in the 1990 NEHRP reauthorization legislation. That legislation calls for NSF to support studies in the earth sciences, earthquake engineering, and the social sciences which complement the activities of the other principal NEHRP agencies.

Since an integrated body of knowledge is needed for coping with earthquake hazards, NSF encourages researchers to conduct cross-disciplinary research and to share the results of their efforts with those both within and outside their own disciplines. However, intellectual integration is difficult to achieve and much remains to be done to facilitate this.

Earthquake research activities are supported at NSF in both the Geosciences and Engineering Directorates. Fundamental earthquake research is supported in the Geosciences Directorate, while the Engineering Directorate funds earthquake engineering research and social science research related to earthquake hazard mitigation and preparedness. Significant progress is being made through these programs in understanding plate tectonics and earthquake processes, geotechnical and structural engineering, and the social and economic consequences of earthquakes.

NSF has attempted to further the advancement of knowledge dealing with earthquake hazards and techniques for coping with these by enabling talented individual investigators, university consortia and centers to conduct both fundamental and focused research. for example, the new world-wide on-line seismic network installed under NSF support provided data for NSF-supported university research groups that developed a rapid model of an earthquake's size, location, and orientation. The signals and solutions are available on e-mail via the Internet and are now routinely used for emergency response to earthquakes and tsunamis in the U.S. and around the world. individuals and teams of researchers supported by NSF continue to make major contributions to earthquake hazard mitigation through analytical, experimental, and field investigations.

Timely studies done in conjunction with the other NEHRP agencies using such events as the 1989 Loma Prieta earthquake, the 1992 Landers earthquake, and the January 17, 1994 Northridge earthquake as natural laboratories, are producing significant results which are being disseminated to potential users across the nation. For example, a Loma Prieta Clearinghouse was created under NSF sponsorship to serve as the national focal point for the collection and dissemination of information on the Loma Prieta earthquake. Also the NEHRP agencies sponsored a symposium which was held on March 22-23, 1993 that considered the implications of the Loma Prieta earthquake for hazard reduction in the nation. Over 400 professionals attended this symposium, including earth scientists, structural engineers, architects, and emergency managers. The seismic hazard in southern California is currently being reviewed in light of new data from recent earthquakes and new technology by the NSF-supported Southern California Earthquake Center in collaboration with

the U.S. Geological Survey and the State of California. Results of this important study, "Future Seismic Hazards in Southern California", are divided into two parts: Phase I deals with the immediate implications of the 1992 Landers earthquake sequence, and Phase II is a complete re-analysis of the seismic hazard in greater southern California. Phase I has been distributed to agencies and the public and Phase II is in its final stages.

RESEARCH CENTERS

Let me say a word about research centers since they play a prominent role in NSF's activities. The National Center for Earthquake Engineering Research (NCEER) was established at the State University of New York in Buffalo with a five-year award from NSF in 1986 and was renewed for another five-year period in 1991, contingent upon continued progress and the availability of NSF funds. NCEER was created to further strategic problem-focused research in earthquake engineering that would be integrated with investigations from seismology and the social sciences. NCEER is also expected to advance the dissemination and transfer of research results to user groups, and to leverage NSF funds with support from other sources, including the State of New York, industry, and other organizations. Working with a consortium of institutions and representatives from industry and government, NCEER has made major progress to date, focusing on seismic-safety research related to buildings, nonstructural elements, lifelines and bridges. One measure of NCEER's success is that the results of some of its problem-focused research have been adopted by practitioners and code groups from California to the Central U.S. and East Coast.

The Southern California Earthquake Center (SCEC) was established in 1991 to integrate and advance the science of earthquake hazard estimation and reduction in a specific region. SCEC is an NSF Science and Technology Center and is supported in collaboration with one of our NEHRP partners, the U.S. Geological Survey. SCEC has successfully integrated the resources of the region's major universities, city and county governments California Office of Emergency Services and Division of Geology, and federal agencies in a concerted response to the earthquake threat. A good example of this unparalleled capability is the leading focus that SCEC supplied to the immediate scientific response to the 1992 Landers and 1994 Northridge earthquakes and a reevaluation of future earthquake hazard of the region. This reevaluation for the first time integrates knowledge from seismicity, new geodetic technology, new geologic discoveries, and local site conditions in an exciting new framework of earthquake hazard evaluation.

DISSEMINATION/EDUCATION ACTIVITIES

NSF, then, supports a range of research activities, some of which involve fundamental questions and others which are more problem focused in nature. This research represents the initial stage in the earthquake hazards reduction process. To the extent that they learn about the results of this research, it can form the basis for action by earthquake hazards reduction professionals. Thus it is important that we disseminate the results of such research to potential users. For this reason, NSF facilitates research utilization through multiple mechanisms, including publications, on-line data centers, computer networks, the education and training of the next generation of researchers and practitioners, information clearinghouses, and such dissemination activities as workshops, conferences and seminars. NSF also supports research on the factors that facilitate and hinder implementation in the earthquake field.

We believe that NSF has been successful in providing the knowledge base—in the earth sciences, earthquake engineering, and the social sciences—that has facilitated hazard mitigation actions throughout the nation. For example, research results from NSF sponsored projects have served as the foundation for the implementation activities of other partners in the earthquake field. The work by NIST, FEMA, the Applied Technology Council, and the Building Seismic Safety Council, which has resulted in the NEHRP recommended provisions for earthquake-resistant building design, would not have been possible without the prior work sponsored by NSF. These provisions have been adopted by the nation's principal code bodies and thus are having a very significant impact on our readiness to counter large earthquakes. Similarly, regional organizations like the California Office of Emergency Service's Earthquake Program, the Central United States Earthquake Consortium and many local organizations are using results from NSF projects that are relevant to their earthquake preparedness activities.

Although much remains to be done and technology transfer is a continuous process, our work is clearly reaching and being used by many professional designers,

planners and emergency managers in areas at risk to earthquakes. The consensus is that the Loma Prieta, Landers and Northridge earthquakes would likely have caused far more deaths and injuries, would have resulted in much greater property loss, and would have far exceeded the actual social and economic disruption had it not been for the research and related activities carried out by NSF and the other NEHRP agencies, along with the actions of local and State officials and the private sector. These earthquakes, as tragic as they were, fell far short of the consequences felt by the people who experienced a similar-sized earthquake in Armenia in 1988. Unfortunately, the people of Armenia did not have the benefit of the type of information available to building designers, planners and emergency managers in the U.S. which resulted in greater protection for the U.S. population.

## THE FUTURE

NSF will continue to seek a proper balance between support for both fundamental and strategic problem-focused research. The former remains important because it provides the underpinning for our strategic research, and the problem-focused efforts are vital because they facilitate rapid movement towards the development of effective earthquake hazard reduction measures. Our decisions on what problem-focused research NSF should consider supporting will rely increasingly on NEHRP's strategic planning process which is now taking shape. Remaining important too will be input that is received from the research and user communities through our various advisory committees and from such mechanisms as research and user conferences and workshops. The reviews of the nation's earthquake hazards reduction activity being carried out by the Office of Science and Technology Policy and the Office of Technology Assessment will also be important in shaping NSF programs in the future.

A workshop held in Washington, D.C. on June 17-18, 1993 to discuss directions for NSF research in the next decade and its role in NEHRP deserves special mention. A select group of forty researchers and practitioners participated in the workshop, along with representatives from the NEHRP agencies. The workshop provided an excellent forum for the discussion of past NSF accomplishments, its role in fundamental and problem-focused research, and opportunities for future research. Participants credited NSF with making significant contributions to NEHRP and hazard reduction in the nation over the years. The consensus also emerged that NSF should continue to give attention to fundamental research as well as continue to fund the more problem-focused type of projects that have emerged in recent years, such as those that have been funded through our Seismic Repair and Rehabilitation of Existing Hazardous Buildings and Precast Seismic Structural Systems initiatives. The latter are not the tightly managed efforts suggested by the National Advisory Committee in its report, but NCEER was established in part to carry out such activities, and they can continue to do so. Indeed, the major highway projects now being carried out by NCEER, under Federal Highway Administration (FHA) sponsorship, and SCEC, under California Department of Transportation and City and County of Los Angeles sponsorship, clearly fall into the genre of managed problem-focused research.

One way of looking at the earthquake hazard across the country is to view it as a problem separate from and unrelated to other challenges facing the nation. However, we feel that this is short sighted and that perhaps the best approach to finding solutions to this problem is to see it in broader systems terms and thus confront it at the same time that related problems are being dealt with, maximizing limited resources in the process. For this reason, NSF sees the seismic threat in the context of badly needed improvements in the nation's infrastructure which, if not properly addressed, could result in continued deterioration in our quality of life and impairment of our ability to compete on the global economic scene. In a major NSF workshop and subsequent publication, earthquake research related to such elements as buildings and power systems was defined as vital for solving key infrastructure problems in the U.S. NSF has planned a major new research initiative on Civil Infrastructure Systems (CIS) and earthquake research will play a vital role in this effort. The involvement of NSF earthquake investigators in future CIS research should make more resources available to them and, even more importantly, should complement he role they presently play in NEHRP.

We expect that the earthquake research programs at NSF will contribute to our CIS efforts by focusing on such topics as vulnerability assessment technologies; retrofit, repair and replacement techniques; smart materials and advanced structural systems; and intelligent control systems. Efforts will be made to carry out such work in partnership with other organizations in both the public and private sectors. MEHRP provides a very good model of just how such partnerships can be forged.

NCEER has already shown significant leadership in linking earthquake research with efforts to improve the nation's civil infrastructure. It has received a six-year $14.2 million award from the FHA to conduct research on seismic hazards related to highway construction. The funds will enable NCEER to pursue research leading to the design of more seismic resistant new highway systems, including roads and bridges, and the rehabilitation of existing systems. This new research program is integrated with NCEER's continuing research activity that is being supported by NSF and the State of New York.

RESPONSE TO THE NORTHRIDGE EARTHQUAKE

Now let me make a few final comments about the NSF response to the January 17, 1994 Northridge earthquake. Like NSF-sponsored post-earthquake investigations in the past, our activities have been closely coordinated with those being carried out by the other NEHRP agencies.

NSF and other NEHRP agency officials were in contact with each other on the day of the earthquake when it became clear that the earthquake would have significant impact on the Los Angeles area. The NEHRP agencies discussed plans to learn mitigation lessons from the earthquake, which would initially involve the collection of perishable data and information, and the need to organize a long-term program of studies that would support future mitigation and preparedness efforts in California and the rest of the nation.

Immediately after the earthquake, interdisciplinary teams sponsored by NSF moved to the earthquake site to conduct postdisaster audits and to collect crucial perishable data on strong ground motions, impacts on buildings and civil infrastructure systems, and social and economic effects. The Southern California Earthquake Center had a particularly important role to play because it is located in the impacted area and is focused on the earthquake hazard in southern California. Other organizations that sent teams to the area and made major contributions to these early investigations include the National Center for Earthquake Engineering Research and the Earthquake Engineering Research Institute.

Portable instruments were immediately transported to the impacted area to collect data on the numerous aftershocks; this information will provide insight into the causes of the earthquake and the nature of future risks.

To expeditiously increase the number of needed post-earthquake investigations. NSF used the strategy of making fast-track funding available to investigators through our Small Grants for Exploratory Research Program and by providing supplemental funding to several existing projects.

During the time that the attention of the NEHRP agencies has focused on initial data collection efforts, plans to carry out a program of intermediate and long-term investigations of the earthquake and related activities have also evolved. The NEHRP agencies have met on a regular basis since the earthquake to develop such plans, which will soon be implemented as the result of a $15 million special appropriation from Congress. A coordinated program of research, information dissemination, and mitigation activities will be carried out internally by FEMA, USGS, and NIST. An external research program will be carried out through NSF in partnership with the other NEHRP agencies focusing on learning lessons from the Northridge earthquake on the hazard environment, the built environment, and socioeconomic impacts. These cooperative NEHRP activities offer the promise of major advances in earthquake hazard mitigation in the nation.

Initial studies of the Northridge earthquake have again demonstrated how much we still have to learn about such events. For example, the extremely large ground motions measured in the Northridge earthquake have changed our ideas about how large earthquake ground motions can be. This new insight is in part related to the nature of the Northridge earthquake fault, a newly recognized class termed "blind thrust fault" that underlies much of southern California and other parts of the world. An immediate challenge for research is to determine the implications of this new knowledge for the built environment.

Finally, we at NSF look forward to our continued cooperation with FEMA, USGS and NIST under the NEHRP banner as we work to achieve, in partnership with local, State, private-sector groups, and other Federal agencies, the national goal of increased earthquake hazard reduction.

Senator ROCKEFELLER. Thank you.

**STATEMENT OF DR. RICHARD WRIGHT, DIRECTOR, BUILDING AND FIRE RESEARCH LABORATORY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY**

Dr. WRIGHT. Mr. Chairman, members, I appreciate the opportunity to testify for the National Institute of Standards and Technology on the reauthorization of the National Earthquake Hazard Reduction Program. In the National Earthquake Hazard Reduction Program, the National Institute of Standards and Technology is responsible for problem-focused research and development to improve building codes and standards and practices for structures and lifelines. This role complements the lead agency role of the Federal Emergency Management Agency, the applied earth sciences role of the U.S. Geological Survey, and the fundamental engineering and earth sciences roles of the National Science Foundation.

The National Institute of Standards and Technology also is responsible for chairing and providing technical secretariat support to the Interagency Committee on Seismic Safety and Construction, through which 30 Federal agencies concerned for seismic safety collaborate to develop and incorporate earthquake hazard reduction measures in their programs.

The vision of the earthquake program is that earthquakes are inevitable natural hazards but need not be inevitable disasters. In spite of its limited resources in NEHRP, NIST has made substantial contributions to achieving the vision of the problem. We look forward to further and accelerated progress.

Our appropriation in fiscal year 1994 is $1,532,000. In addition, we received $1.5 million from the emergency supplemental appropriation for investigation of the effects of the January 17 Northridge earthquake. Other funding has been provided by other Federal agencies, such as FEMA and the Department of Housing and Urban Development, for technical support of their programs. I would note that the authorization provided for in H.R. 3485 for fiscal years 1995 and 1996 does not accommodate the President's request of $1,932,000 for NIST for fiscal year 1995.

NIST has participated in the meetings of the Policy Coordinating Group, made up of the Presidential appointees of each principal agency that are responsible for its work in NEHRP. This group has provided policy-level direction in preparation of the coordinated and consolidated budget and its presentation to the Office of Management and Budget, the development of the 5-year plan, the initiation of strategic planning, and the establishment of the NEHRP advisory committee.

I have represented NIST in the Interagency Coordination Committee, whose members are the senior line managers of the participating agencies. This provides management direction in the preparation of the budget for NEHRP, its presentation to the Office of Management and Budget, the development of the 5-year plan, and the preparation of the strategic plan.

As I mentioned, we provide the secretariat and the chairmanship for the Interagency Committee on Seismic Safety and Construction. This has provided support for the implementation of Executive Order 12699, Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction, development of recommendations for standards for assessing and enhancing the seis-

mic safety of existing Federal buildings, and planning for developing and adopting seismic standards for lifelines.

As a result of the special supplemental funding provided for investigations following the 1989 Loma Prieta, NIST has been able to conduct problem focused engineering research to address a number of major needs for improvement of seismic design and construction practices. With this special supplemental funding, it was possible for us to collaborate in the studies with leading researchers from universities and the private sector. Over 70 reports and papers have been published and disseminated to the earthquake engineering community by NIST since fiscal year 1991.

Furthermore, the emergency supplemental funding for study of the effects of the 1994 Northridge earthquake will allow NIST to address certain critical issues in collaboration with academic and private sector researchers. These include the performance of cladding, steel-framed buildings, rehabilitation of unreinforced masonry buildings, guidelines and criteria for electrical power systems, and fire protection systems.

The losses from the Northridge earthquake on January 17 are estimated to be a total loss, including indirect economic effects, of $30 billion. It could be the costliest natural disaster in U.S. history. Severe ground shaking caused damage to over 11,000 homes, residential buildings, and commercial structures. Six major highway structures collapsed and damage to over 150 highway overpasses occurred.

In addition, there was loss of power and water supply to tens of thousands of residents for an extended period of time, as well as fires that destroyed houses and mobile homes in several mobile home parks. If it had not been for the earthquake occurring on a holiday, at a time when most people were home in the safest buildings, small homes, the losses could have been much larger than the reported 58 deaths.

NIST, working with the member agencies of the Interagency Committee on Seismic Safety and Construction, participated in the postearthquake investigation to observe and document the performance of various infrastructure systems, and published its report in March 1994. And with your permission, Mr. Chairman, I will offer the report for the record.

[The information referred to may be found in the committee files.]

Dr. WRIGHT. The National Earthquake Hazard Reduction Program gains greatly from international and national collaborations in learning about earthquake effects, mitigation practices, and implementation mechanisms. I would note that the U.S.-Japan Panel on Wind and Seismic Effects is right now meeting in Gaithersburg, MD, bringing together 16 U.S. agencies and 6 Japanese agencies to work collaboratively on improving the resistance to severe winds and to earthquakes, and to collaborate in research activities.

The earthquake program depends strongly on professional and industry associations in the United States for development of education in and implementation of earthquake hazard reduction practices. NIST has been successful in encouraging collaborative activities and participating in and leading the work of collaborating organizations.

Our longer statement describes some of the key national and international activities in which we participate.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Wright follows:]

PREPARED STATEMENT OF DR. RICHARD N. WRIGHT

Mr. Chairman and members, I appreciate the opportunity to testify for the National Institute of Standards and Technology (NIST) on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP).

INTRODUCTION

In the National Earthquake Hazards Reduction Program, NIST is responsible for problem-focused research and development to improve building codes and standards and practices for structures and lifelines. This role complements the lead agency role of the Federal Emergency Management Agency (FEMA), the applied earth sciences role of the U.S. Geological Survey (USGS) and the fundamental engineering and earth sciences research role of the National Science Foundation (NSF). NIST also is responsible for chairing and providing technical secretariat support to the Interagency Committee on Seismic Safety in Construction (ICSSC) through which Federal agencies concerned for seismic safety collaborate to develop and incorporate earthquake hazard reduction measures in their programs.

This testimony covers:

—Funding for NIST in NEHRP,

—Participation in and perspectives on the management and planning of NEHRP,

—Support for developing and implementing earthquake hazard reduction practices,

—Problem-focused engineering research,

—Post-Northridge Earthquake Reconnaissance Investigation, and

—National and international collaborations for earthquake hazard reduction.

The vision of NEHRP is that earthquakes are inevitable natural hazards, but need not be inevitable disasters. In spite of its limited resources in NEHRP, NIST has made substantial contributions to achieving the vision of NEHRP; we look forward to further and accelerated progress.

FUNDING FOR NIST IN NEHRP

NIST's appropriation for NEHRP in Fiscal Year 1994 is $1,532,000. In addition, NIST received $1,500,000 from the Emergency Supplemental Appropriation for investigation of the effects the January 17, 1994 Northridge earthquake. Additional funding has been provided by other Federal agencies, such as FEMA and the Department of Housing and Urban Development (HUD), for technical support of their programs. Table 1 shows NIST's NEHRP funding for Fiscal Years 1992 through 1994. The authorization provided in H.R. 3485 for Fiscal Years 1995 and 1996 does not accommodate the President's request of $1,932,000 for NIST for FY 1995.

MANAGEMENT AND PLANNING OF NEHRP

NIST has made significant contributions toward the management and planning of NEHRP.

The director of NIST has participated in the meetings of the Policy Coordinating Group (PCG), made up of the Presidential appointees of each principal agency that is responsible for work in NEHRP. The PCG has provided policy-level direction in the preparation of the coordinated and consolidated budget for NEHRP and in its presentation to the Office of Management and Budget, in the development of the Five Year Plan for NEHRP, in the initiation of strategic planning, and in the establishment of the NEHRP Advisory Committee.

I have represented NIST in the NEHRP Interagency Coordinating Committee (ICC), whose members are the senior line managers of the principal agencies. The ICC provides policy-level direction in the preparation of the coordinated and consolidated budget for NEHRP and in its presentation to the Office of Management and Budget, in the development of the Five Year Plan for NEHRP, and in strategic planning. The ICC also coordinates the execution of the NEHRP program, including the preparation of Congressionally-mandated studies and collaboration with private and public sector elements of the earthquake community, and the development of the biennial NEHRP report to Congress.

NIST chairs and provides technical secretarial support for the Interagency Committee on Seismic Safety in Construction (ICSSC). Through ICSSC, thirty (30) Fed-

eral agencies concerned with seismic safety collaborate in developing and incorporating earthquake hazard reduction measures in their programs. ICSSC continues its strong support for the implementation of Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction," for the development of recommendations for standards for assessing and enhancing the seismic safety of existing Federal buildings, and for planning the development and adoption of seismic standards for lifelines. These activities are updated in Section 4.

NIST has worked closely with the community concerned with earthquake safety to determine research needs and implement research results. NIST participated actively in the deliberations of the NEHRP Advisory Committee. With regard to the principal recommendations of the Advisory Committee report of January 29, 1993, NIST feels that:

- NEHRP has been the subject of successful efforts to improve management team work; such efforts should be sustained and possibly improved as a result of the Administration's review of the National Earthquake Hazard Reduction Programs. Policy issues can be resolved by the PCG. Scheduling constraints can be overcome by allowing designees of the PCG members to represent and commit their agencies. Planning and implementation of the program can be the responsibility of the ICC with a clear requirement for each agency to keep the others informed of and involved in activities affecting them.
- Incentives, not regulations, should be used to achieve implementation of earthquake hazard reduction measures by the private sector and State and local governments. Since earthquakes are but one of many natural and manmade hazards that must be considered in the design, construction and use of constructed facilities, earthquake hazard mitigation practices should be an integral part of the voluntary standards and State or local regulations that govern safety measures. Incentives can include the life cycle cost savings to be gained from avoiding the loss of function, property and lives; reduced insurance premiums; and, eligibility to participate in Federal assistance programs such as loans from Federally insured institutions and Federally-insured loans. The latter incentive has been effective in implementation of Executive Order 12699. All nationally recognized model building codes have adopted up-to-date seismic provisions for new buildings that now are being adopted and enforced by State and local governments.
- Enhanced efforts are needed in problem-focused engineering research to develop and implement cost- and performance-effective seismic practices for existing and new buildings and lifelines. NIST has been active in problem-focused engineering research, as described subsequently in this statement, and is prepared technically for playing a larger role in the conduct, sponsorship and management of this research.
- Quantitative vulnerability assessment methods are needed to define and demonstrate cost effective risk reduction measures. We must appreciate the costs of not reducing risks to determine the appropriate investment in risk reduction. NIST's capabilities in predicting structural performance and in economics can contribute substantially to these studies.

## DEVELOPMENT AND IMPLEMENTATION OF EARTHQUAKE HAZARD REDUCTION PRACTICES

In accord with P.L. 101-614, NIST provides the chair and secretariat for the Interagency Committee on Seismic Safety in Construction (ICSSC) through which 30 Federal agencies concerned for seismic safety collaborate to develop and incorporate earthquake hazard reduction measures in their programs. FEMA funds the work of the ICSSC secretariat. To link its activities to those of the private sector, the ICSSC chair serves as a member of the Board of the Building Seismic Safety Council (BSSC), and ICSSC members serve on many technical committees of BSSC.

### *Implementation of Executive Order*

Following the President's issuance of Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction," in January 1990, NIST and ICSSC undertook a number of activities in support of the Executive Order's implementation.

To facilitate State and local building codes acceptable to the Executive Order, NIST provided funding to translate the "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings" into language suitable for incorporation into the National and Standard model building codes and into language suitable for incorporation in the American Society of Civil Engineers' Standard A7, "Minimum Design Loads for Buildings and Other Structures." In 1992 both the National Building Code and the Standard Building Code have adopted the requirements of the NEHRP recommended provisions.

A study was conducted for the ICSSC on the equivalence to each other of the NEHRP-recommended provisions, of the seismic provisions of the Uniform Building Code, and of the National Building Code and the Standard Building Code—the three nationally-recognized model building codes. In March 1992, ICSSC issued a Recommendation that the seismic provisions of the current editions of the three model building codes are appropriate for implementing the Executive Order. This recommendation is very important for cost-effective seismic safety. The designer of a Federal, or Federally-assisted or regulated building, can use the model building code familiar to the locality without incurring either the expense or the possibility of misunderstanding involved with the use of an unfamiliar special Federal seismic requirement.

To assist Federal agencies in the implementation of the Executive Order, the ICSSC developed "Guidelines and Procedures for the Implementation of the Executive Order on Seismic Safety of New Building Construction" and a model preamble for use by agencies developing regulations or rules for implementation of the Executive Order in agency programs. The National Conference of States on Building Codes and Standards developed for NIST a report titled "Seismic Provisions of State and Local Building Codes and Their Enforcement." This report will assist Federal agencies in identifying the model building code used in any given locality so that the use of the seismic provisions of the current edition of the model code can be required as a condition of design and construction under the purview of the Executive Order. NIST further organized workshops for Federal agencies on the development of regulations or rules for implementation of the Executive Order. NIST staff have made numerous presentations at national and regional meetings of design professionals and emergency managers on the requirements of and implementation of the Executive Order.

In 1993 an effort was made to weaken the seismic provisions of the Standard Building Code. ICSSC conducted a study to assess the impact of the proposed changes. ICSSC, the Building Seismic Safety Council, and a leading building official testified against the proposed changes and achieved the 75 percent vote required to maintain the integrity of the seismic provisions of the Standard Building Code.

*Standards for Seismic Safety of Existing Federal Buildings*

P.L. 101-614 calls for ICSSC to work with appropriate private sector organizations in the development of standards for assessing and enhancing the seismic safety of existing buildings constructed for, or leased by, the Federal government. The President is to adopt the standards by December 1, 1994. With funding from FEMA, NIST has worked with leading consulting engineering firms to draft a proposal for the standards, balloted the proposal and obtained approval of ICSSC, and consulted with the private sector in the balloting process.

The standards for assessing seismic safety of existing Federal buildings are based on a document prepared by the Building Seismic Safety Council for FEMA (NEHRP Handbook for the Seismic Evaluation of Existing Buildings). Concurrently, BSSC/ATC/ASCE jointly are developing Guidelines for the Rehabilitation of Existing Buildings. This effort will, in about 1998, lead to national consensus standards that can then supplement the Federal standard.

In order to ensure the consistent application of the standards for existing Federal buildings throughout the government and the expeditious implementation of the standards, the ICSSC has developed a proposed Executive Order for the President's consideration. Both the Standards and the proposed Executive Order have been forwarded to FEMA for transmittal to the Office of Management and Budget.

*Plan for Seismic Standards for Lifelines*

Lifelines are the public works and utilities systems that support most human activities: family, economic and cultural. Lifeline systems include electrical power, gas and liquid fuels, telecommunications, transportation, and water supply and sewers. Failures of lifelines can be directly hazardous to life; examples are spills of flammable liquids, conflagrations, explosions and collapses of structures. Often more significant are indirect consequences of failures; examples include unlivability of homes without power, fuel or transportation, and losses of employment and production without lifeline services. The January 17, 1994, Northridge earthquake in the Los Angeles area showed the impact on a region of lifeline system failures and interruptions. A description of these impacts is given in Section 6 of this statement.

With funding from FEMA and NIST, NIST, working with appropriate private sector organizations and the NEHRP Advisory Committee, has developed the "Plan for Developing and Adopting Seismic Guidelines and Standards for Lifelines," as called for in P.L. 101-614. The Plan focuses on developing recommendations for guidelines and standards, testing and improving these recommendations in demonstration

projects, encouraging and supporting the approval of these recommendations by the standards and professional organizations serving the lifeline community, and working with the lifeline community to achieve their effective implementation. Since lifelines are long-lived and regularly maintained, the Plan emphasizes the assessment and mitigation of hazards of existing lifelines. The Plan is in review by FEMA and OMB for submittal to Congress. The lifeline community is eager to initiate work on lifeline guidelines and standards.

## PROBLEM-FOCUSED ENGINEERING RESEARCH

As a result of the special, supplemental funding provided for investigations following the 1989 Loma Prieta earthquake, NIST has been able to conduct problem focused engineering research to address a number of major needs for improvement of seismic design and construction practices. Furthermore, the emergency supplemental funding for study of the effects of the 1994 Northridge earthquake will allow NIST to address specific issues in collaboration with academic and private sector researchers.

Note also, with this special, supplemental funding it was possible for NIST to collaborate in the studies with leading researchers from universities and the private sector. A list of recent publications from NIST problem-focused engineering research is attached as Appendix A. Collaborators in the research are noted for each project.

### *General Structural Performance*

#### *Site Specific Definition of Seismic Loads*

The effects of Subsurface Conditions on Earthquake Ground Motions were studied in collaboration with the University of California, Davis. The widely used computer program SHAKE for calculating the seismic response of semi-infinite, horizontally layered soil deposits was revised to increase the number of soil layers that could be modeled, provide for user-specified moduli and damping relationships and make the program conveniently usable on a personal computer. SHAKE results derived from bedrock motions measured during the earthquake and measured soil properties were compared to ground surface measurements. (Since bedrock motions were not available directly below the ground surface measurements, analyses were based on bedrock motions measured at similar epicentral distances.) Although the measured earthquake intensities are generally less than the design earthquake intensities for the measurement sites, results show that current design criteria underestimate the amplitude of ground motions at periods of less than 2 seconds.

#### *Criteria for Passive Energy Dissipation Systems*

Studies of criteria for passive energy dissipation systems have considered the durability of elastomeric isolation bearings and the force levels for which base-isolated buildings should be designed. Experiences and standards related to the non-seismic uses of elastomeric bearings, for instance as bridge bearings, are related to the performance and durability requirements of seismic isolation bearings. Non-linear, time-history analyses of the response of steel moment frames, steel braced frames, concrete moment frames and concrete shear walls, designed to 25, 50 or 100 percent of the resistance for fixed-base structures, show that equivalent behavior for base isolated systems is obtained with 25 to 50 percent of the resistance required for fixed-base structures.

Testing has become an essential element in the design and construction of seismically isolated structures built in the U.S. Testing of the isolation system prior to installation is required by each of the existing building codes that deal with the design of isolated structures; however, standards do not yet exist for conducting these much needed tests, and therefore, test procedures and results are subject to considerable variability. NIST has recently completed the development of draft guidelines, a pre-standard, for the testing of isolation systems. The guidelines address pre-qualification, prototype and quality control testing. This work was conducted in collaboration with an oversight committee of experts from universities and industry. Work to develop the final guidelines is currently underway. The final guidelines will be based on feedback from industry review of the draft guidelines.

#### *Condition Assessment Using NDT Methods*

NIST studied the capability of commercial electromagnetic covermeters to locate and determine the size of reinforcing bars in concrete. Such meters are relatively insensitive to bar size and additional deeper layers of bars or presence of splices in depth. Recommendations are provided for developing a standard test method and for improvements of meter performance. This work complements earlier NIST development of the impact-echo method for locating flaws at depth in concrete structures.

*Partially Reinforced Masonry Walls*

NIST compared results available from U.S. and foreign tests of fully- and partially-reinforced masonry shear walls to predictive equations for the ultimate flexural and shear resistance. Partially-grouted masonry, in which vertical reinforcement is concentrated in a few cells and only those vertical cells containing reinforcement are grouted, promises to be a cost-effective measure for construction of masonry buildings in moderately seismic regions. The Council for Masonry Research has also suggested that NIST investigate the replacement of bond beams, which contain the horizontal reinforcement needed to resist horizontal shear forces generated by the seismic motions, with bed joint reinforcement, which are electrically-welded grids of reinforcing wire. This replacement also has a high potential for improving the productivity and enhancing the cost-effectiveness of the U.S. masonry construction industry. NIST staff have developed a detailed plan for a comprehensive, multi-year experimental and analytical investigation on the shear strength of partially grouted masonry shear walls. The experimental data is needed to calibrate an empirical expression developed by NIST staff for predicting the shear strength of partially-grouted masonry walls, as well as to verify existing finite element model of masonry shear walls.

*Performance of Buildings*

*Evaluation of the Performance of Seismically Retrofitted Buildings*

NIST supported the Applied Technology Council to evaluate the effectiveness of seismic retrofitting methods in the Whittier Narrows and Loma Prieta earthquakes. Improved structural performance was gained by thorough retrofit of unreinforced masonry (URM) and tilt-up buildings. Arbitrary and incomplete retrofitting may not significantly improve performance compared to unretrofitted buildings. Sufficient data are not now available to conduct a detailed evaluation of retrofitting methods used for buildings other than URMs and tilt-ups. However, no serious damages were observed of retrofitted steel, concrete, and timber structures during the Whittier Narrows and Loma Prieta earthquakes.

*Response Characteristics of Full Scale Buildings*

In cooperation with the U.S. Geological Survey and the California Division of Mines and Geology, dynamic properties of buildings derived from ambient vibration data were compared to those derived from strong motion measurements during the earthquake. Natural periods of vibration are smaller in ambient vibrations. Soil-structure interaction can be responsible for 3 to 4 times increases in damping and, consequently, substantial reductions in earthquake-induced forces and deformations.

*Strengthening Methodologies for Reinforced Concrete Frame Buildings*

In collaboration with Cornell University and the National Center for Earthquake Engineering Research, system identification methods were used to develop (1) hysteresis failure models for use in inelastic time history analysis, and (2) empirical formulas for quick calculation of strength, drift ratio, and ductility, of bare frames and frames strengthened by infill walls. Both methods were validated by comparing analytical results with existing experimental results and are available for direct use in design and for preparing guidelines.

*Seismic Performance of Precast Concrete Beam-to-Column Connections*

In collaboration with the American Concrete Institute and the Structural Engineers Association of California, analytical and experimental studies have been conducted of the strength, stiffness, ductility and energy absorbing capacity of precast concrete beam-to-column connections. Practical details and design criteria are being developed to provide behavior equal to or better than monolithic beam-to-column connections for moderate and high seismic zones.

*Performance of Non-structural Components*

The study will develop recommended provisions for the seismic design of non-structural components in buildings. Non-structural components include such elements as suspended ceilings, exterior cladding panels, water pipes, ventilating ducts, window glass, furniture, and mechanical equipment. Damage to non-structural components in earthquakes often costs as much as damage to the structure itself. Current practices for seismic design of non-structural components are being evaluated. A detailed study of critical non-structural components will follow to develop recommended provisions for seismic design of non-structural components.

*Seismic Resistance of Joints in Precast Concrete Shear Walls*

Precast concrete structures are seldom used in seismically-active regions of the U.S. due to unnecessarily restrictive design criteria in current building codes and

standards. An experimental program is underway at NIST to evaluate the seismic resistance of a variety of connection details for vertical and horizontal joints in precast concrete shear walls. The experimental data from this program are needed to verify proposed design procedures for such connections, as well as to calibrate current analytical models for precast concrete structural systems. NIST staff, working in close cooperation with the design and construction industry, have identified and developed six connection details each for vertical joints and horizontal joints in precast concrete shear walls. These details promise improved seismic performance while maintaining the cost-effectiveness of precast concrete construction. Experimental work is now underway using a test facility which applies simulated seismic loads.

*Performance of Bridges*

*Inelastic Damage Analysis Applied to Double-Deck Highway Structures*

In cooperation with the State University of New York at Buffalo, Cornell University and the University of Central Florida, the Inelastic Damage Analysis of Reinforced Concrete Structures program was extended to model the seismic response of the Cypress Viaduct structure which collapsed during the 1989 Loma Prieta earthquake. Shear failure of the pedestal regions was predicted in agreement with the assessment of the California Governor's Board of Inquiry. The analytical method developed can be used to examine retrofit options for double-deck structures.

*Seismic Design of Bridge Columns*

An integrated system design procedure for seismic loads has been developed and demonstrated for the seismic design of bridge columns. In the procedure, an ensemble of bedrock time histories is amplified by overburden soil conditions to drive a non-linear, hysteretic model of the structural system response. Optimum design procedures are employed to achieve desired behavior at minimum cost. Results assess the reliability of current design criteria as functions of magnitude, epicentral distance, overburden soil profile, and structural proportions. Recommendations are provided for spiral reinforcing required for adequately ductile bridge column behavior.

*Seismic Assessment, Repair and Retrofit of Bridges*

With funding from NIST, the University of California at San Diego studied assessment, repair and retrofit methods for bridge structures. The current status of research on retrofit was examined and techniques used to repair and strengthen existing bridge structures in the U.S. and other countries were reviewed. Guidelines were prepared for assessment, repair and retrofit of bridges. The approach to seismic assessment is based on the mechanism force/displacement of the structural system rather than the traditional capacity/demand approach. Recommendations are made for further research, design studies and development of design and retrofit practices.

*Lifeline Earthquake Engineering*

*Estimating Soil Parameters Using System Identification Techniques*

Liquefaction causes a large portion of all damage during earthquakes. The damage is especially severe to lifeline structures such as pipelines. This research examined the state-of-the-art of the application of System Identification (SI) methods to the liquefaction problem, with special attention to lifelines. System Identification was shown to be a promising method to ascertain large strain soil properties in-situ.

*Estimating In-Situ Liquefaction Potential and Permanent Ground Displacement Due to Liquefaction*

The study examined in-situ methods of estimating liquefaction potential. In situ methods are preferred since it is impossible to test in the laboratory "undisturbed" samples of loose soil deposits, which are most susceptible to liquefaction. The state of practice is the Standard Penetration Test (SPT) based method. The Spectral Analysis of Surface Wave technique is especially suited for examining the large areal extent of lifeline routes. The state of the art for estimating permanent ground displacements is empirical. Several methods are examined; they appear to have roughly equal predictive abilities.

*A Review of the Seismic Vulnerability of Water and Sewer Systems*

Sustained service of water and sewer systems after a major earthquake is vital to citizens' physical and economic well-being. This study reviewed the performance of these lifelines during past earthquakes in the U.S., Japan, and other countries. The most common source of damage was soil displacement. In general, flexible systems performed better than rigid ones, with failures concentrated at connections.

The importance of proper anchorage of movable items cannot be over-emphasized. Key topics for future research include reliable estimation of possible soil displacement, liquefaction susceptibility, nonlinear behavior and soil damping, soil-structure interaction, in-situ improvement of hazard-prone soils, non-destructive evaluation of in-situ pipes, and improved design of connections.

*Post-Northridge Earthquake Studies*

*Seismic Performance of Cladding Systems*

NIST is evaluating the seismic performance of exterior architectural cladding elements during the Northridge earthquake, and developing energy dissipating cladding systems for seismic retrofit and design of new buildings. Although cladding elements are not specifically designed for seismic forces, they participate in resisting lateral loads as they deform with the framing system. Some cladding systems sustained damage during the Northridge earthquake, particularly those on steel frame structures. The seismic performance of buildings could be improved by utilizing effectively the cladding system to dissipate energy and these systems can conceivably be applied to both new construction and seismic retrofit.

*Performance of Rehabilitated Masonry Buildings and Development of Performance-based Rehabilitation Guidelines*

Despite the rehabilitation requirements in Los Angeles, many unreinforced masonry (URM) buildings were badly damaged during the Northridge earthquake. As a life-safety measure, current rehabilitation practices appear to be successful. However, rehabilitation practices were not successful in preventing property damage, often leading to significant economic losses due to building repair time and the associated business disruption. This study will document the performance of rehabilitated URHs buildings, evaluate the effectiveness of current rehabilitation practices, and develop guidelines for rehabilitation beyond life safety.

*Performance of Steel-framed Structures*

Steel-framed buildings have long been considered to be less vulnerable to sustaining serious damage under strong ground shaking when compared with other types of buildings. However, after the Northridge earthquake, engineers uncovered widespread evidence of fractures in steel members and welded joints of steel-framed buildings. The situation is so serious that the State of California issued an unprecedented advisory urging owners whose buildings suffered apparent cosmetic damage to conduct thorough inspections to ensure that building damages were indeed only cosmetic. The study will document damages and analyze the causes of the failure in steel-framed buildings affected by this earthquake.

*Performance of Power Transmission and Distribution Systems*

The Northridge earthquake has demonstrated once again the vulnerability of power system facilities to earthquake damage. Many substations experienced extensive damage to high voltage equipment during the Northridge earthquake, similar to what had happened to these facilities during the 1971 San Fernando earthquake. This earthquake has again demonstrated the vulnerability of emergency power systems (that did not operate at power), communication facilities, emergency operating centers, and numerous other critical facilities. Strong motion records from the earthquake, coupled with the documented damages provide a unique opportunity to perform failure analyses and develop methods to mitigate the effects of future earthquakes on power system facilities. The study will develop guidelines to improve the earthquake response of power distribution system and to develop an equipment fragility data base using the damage information from the Northridge earthquake.

*Performance of Fire Protection Systems*

Some critical facilities, such as hospitals, were evacuated not because of structural damage, but because of the rupture of sprinkler systems. This study is aimed at the examination of the performance of sprinkler systems. It also will study fire causes, and assess the performance of fire fighting operations.

POST-NORTHRIDGE EARTHQUAKE RECONNAISSANCE INVESTIGATION AND PRELIMINARY ASSESSMENT

Earthquakes provide a natural laboratory setting that allows us to evaluate the performance of the built environment when subjected to strong ground shaking. NIST has been participating in post-earthquake reconnaissance activities since the early 1970's. Immediately after the January 17, 1994, Northridge earthquake, ICSSC, with NIST leadership, sent a reconnaissance team to the Los Angeles area to conduct observations of components of the built environment, including bridges,

buildings, and lifelines such as gas and water systems, as well as to assess the causes of fires. NIST published its reconnaissance report entitled "1994 Northridge Earthquake: Performance of Structures, Lifelines, and Fire Protection Systems" in March 1994 and a copy is included with this statement.

The magnitude 6.8 earthquake, which occurred in the San Fernando Valley, resulted in 58 deaths, and an estimated total loss of $30 billion. This earthquake could be the costliest natural disaster in the U.S. history. Strong ground shaking caused severe damage to over 11,000 homes, residential buildings, and commercial structures; six major highway structures collapses; and damage to over 150 highway overpasses. In addition, it resulted in the loss of power and water supply to tens of thousands of residents for an extended period of time, as well as fires that destroyed houses and mobile homes in several mobile home parks.

The ICSSC team had the opportunity to work with a number of other experts also conducting reconnaissance efforts after the earthquake and developed the following preliminary assessment with regard to the earthquake's impact on the built environment.

- Strong ground motions in the epicentral regions were at the maximum intensity considered for design and at many locations exceeded design level. Most modern buildings and life lines performed well. This is evidence of the success of modern seismic standards.
- Although a large number of buildings sustained damage, the number of buildings which experienced total or partial collapse was very limited. Most of the collapsed buildings were built before the building codes were significantly improved in the mid-70's. Most buildings that did collapse either had a structural system known to be vulnerable to earthquake damage, such as unreinforced masonry walls or nonductile concrete frames, or were sited in a situation known to be vulnerable, such as on or below a steep hillside.
- The wide variety of buildings subjected to a wide range of seismic intensity throughout the Los Angeles area provides an exceptional opportunity to improve methods for assessment of seismic vulnerability.
- Many parking structures collapsed. These collapses are potentially life-threatening. The time of occurrence of the earthquake (4:31 a.m.) avoided a large number of deaths and injuries. The unique structural configurations of parking structures suggest that code requirements need to be re-examined to ensure adequate seismic performance. A complete load path is necessary to transmit the earthquake-induced forces to the elements designed to resist them. Structural elements that are not considered a part of the lateral-force-resisting system can fail and initiate collapse if they are not detailed to accommodate drift.
- In the epicentral region, many two- and three-story wood frame apartment structures sustained extensive structural damage. "Soft" first stories, open for parking space, are vulnerable to excessive distortion and collapse. Poor connections between the superstructure and the foundation caused some failures.
- Non-life-threatening damage, such as that caused by losses of ceilings, breakage of sprinkler systems, and breakdowns of HVAC systems, was widespread and in many cases extremely disruptive. Many hospitals and schools were made unusable.
- Rehabilitation of unreinforced masonry buildings using ties to connect walls to floors and roof provided performance as expected. Although total collapses were avoided, falling masonry posed serious life-threatening conditions.
- Many steel-framed buildings experienced brittle failure near welded joints. The joint behavior observed in laboratory tests with small specimens often is extrapolated to predict the behavior of full-scale members. Large-scale tests are needed to affirm or improve the current design requirements for joints in steel-framed buildings which are based on small-scale test results.
- A number of the highway overpass failures were due to collapse of supporting columns. Many of these columns failed due to inadequate transverse reinforcement. Most highway structures designed to criteria developed after the 1971 San Fernando earthquake performed well. However, short flared columns designed after the San Fernando quake sustained severe damage. Further studies are needed to improve the seismic performance of such columns. Highway structures given full retrofit, following studies of the 1989 Loma Prieta earthquake, also generally performed well.
- Although none of the buildings were tested to their design limits, properly engineered, base-isolated buildings performed well during the earthquake. An example of such buildings is the 7-story USC hospital, which was subjected to a peak ground acceleration of 0.37g and remained functional after the quake. No structural damage was reported.

• Fires in this earthquake resulted from the breakage of gas lines as the result of strong shaking. Fortuitously, winds were calm and fires did not spread as they would have with normal winds.

• Inadequately anchored mobile homes were displaced from their supports, gas lines were severed and large fires resulted. Attention is needed to proper installation of mobile homes.

• The major fire on Balboa Boulevard was due to the rupture of a 22 inch cast iron gas main of 1930's vintage. The breakage of the 48 inch water main of pre-1971 construction severely limited the ability to fight the fire at the site. Recently designed and constructed gas and water lines performed well.

### NATIONAL AND INTERNATIONAL COLLABORATIONS

The NEHRP gains greatly from international and national collaborations in learning about earthquake effects, mitigation practices and implementation mechanisms. NEHRP depends strongly on professional and industry associations in the U.S. for development of, education in, and implementation of earthquake hazard reduction practices. NIST has been successful in encouraging collaborative activities, and participating in and leading the work of collaborating organizations.

• NIST participates actively in over 100 national and international standards development activities for construction and fire. NIST also provides volunteer leadership to major standards organizations such as the International Standards Organization, the American Society for Testing and Materials, the American Concrete Institute (ACI), the American Institute of Steel Construction (AISC), the American Society of Civil Engineers (ASCE), and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). Examples of NIST staff's participation relevant to the earthquake engineering program are:

—Dr. Richard N. Wright, Director, Building and Fire Research Laboratory (BFRL) is past chairman and member of the Executive Committee of the ASCE Structures Division

—Dr. H. S. Low, Chief, Structures Division/BFRL, serves on ACI Committee 318, Standard Building Codes and AISC Specification Committee on Steel Construction

—Dr. Richard Marshall, Leader, Structures Evaluation Group, Structures Division/BFRL, serves on ASCE 7, Wind Loads Task Committee and ASCE Executive Committee of Structural Standards Division

—Dr. Riley M. Chung, Leader, Earthquake Engineering Group, Structures Division/BFRL, serves on ASCE Committee on Natural Disaster Reduction, ASCE Steering Committee for the 1996 International Conference on Natural Disaster Reduction, and Program Committee for the 1995 4th U.S. National Conference on Lifeline Earthquake Engineering.

• U.S.-Japan Panel on Wind and Seismic Effects includes 16 U.S. Federal agencies and 9 Japanese agencies. NIST provides the U.S-side chairman. UJNR has:

—held 25 annual technical meetings for prompt exchange of research findings.

—conducted over 40 workshops and conferences, on topics such as repair and retrofit of structures, involving leading U.S. and Japanese researchers and practitioners.

—conducted cooperative post earthquake investigations.

—hosted visiting Japanese researchers and provided access for U.S. researchers to unique Japanese facilities.

—organized cooperative research programs on steel, concrete, masonry and precast concrete structures.

—cooperated in investigations of damaging earthquakes in Japan and U.S.

• International Council on Building Research, Studies and Documentation (CIB). NIST has provided the President 1983-86 and serves on its Board and Program Committee. CIB provides recommendations for international standards on structural resistance to earthquakes and international cooperation on earthquake hazard reduction.

• International Union of Laboratories for Testing and Research on Materials and Structures (RILEM). NIST provided the president 1982-85, and provides continuing leadership in development of its technical programs.

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**TABLE 1—NIST Funding for NEHRP**

[Dollars in millions]

| | Fiscal year 1992 | Fiscal year 1993 | Fiscal year 1994 |
|---|---|---|---|
| NIST Appropriation | 0.932 | 1.332 | 1.532 |

**TABLE 1—NIST Funding for NEHRP—Continued**

[Dollars in millions]

| | Fiscal year 1992 | Fiscal year 1993 | Fiscal year 1994 |
|---|---|---|---|
| Northridge Supplemental Appropriation | 0 | 0 | 1,500 |
| FEMA | 0.817 | 0.244 | 0.180 |
| Other Federal Agencies | 0.162 | 0.099 | 0.337 |
| Private Sector | 0.107 | 0.154 | 0.036 |
| Total | 2.018 | 1.829 | 3.585 |

APPENDIX A—TECHNOLOGY TRANSFER EFFORTS IN EARTHQUAKE ENGINEERING—FY91–FY93—NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY BUILDING AND FIRE RESEARCH LABORATORY

Technology transfer plays a critical role in successfully meeting the NEHRP goals and takes various forms in its implementation. These forms include publication of problem-focused engineering research results in NIST interim reports (NISTIR); in journals, and conference and workshop proceedings; in trade associations, professional societies, and agencies' newsletters; and through speeches given at professional gatherings.

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Updated: May 1994

Senator ROCKEFELLER. Thank you.

And I will just start off with a couple of questions. And, actually, I think I will just jump in on a point that you made at the end, Dr. Wright, about other countries. Obviously, other countries have earthquakes, some experiencing earthquakes to a greater degree than we do. Japan, is a good example.

What do you do to look at what Japan, for example, does in the way of not just protecting their overpasses and the things that we think of, but what you also mentioned, such as electricity, water, gas, which also are part of the infrastructure, and just as dangerous.

In any event, what is it you discuss with them and how long has this been going on and how fruitful is it? And give me some examples of results.

Dr. WRIGHT. Good. I can summarize it, and my colleagues here participate with us on the panels, so they may have some points to add. However, we have been working on the U.S.-Japan Panel on Wind and Seismic Effects since 1969. Now, in comparison to the U.S. National Earthquake Hazard Reduction Program, which is authorized at about $100 million per year, the Japanese earthquake hazard reduction program spends about $2 billion per year. So, we are very fortunate in being able to work closely with the Japanese.

Senator ROCKEFELLER. Of course, they are a much smaller country.

Dr. WRIGHT. And gain from the very major investments that they make. We can use the greatest——

Senator ROCKEFELLER. Well, tell me about that. Tell me, what do they do that we do not do?

Dr. WRIGHT. They have, for instance, the world's largest shaking table that can shake, I believe, 10,000 tons at accelerations that correspond to the accelerations you get in a real earthquake. The largest shaking table we have here in the United States has a capacity of about 100 tons.

Senator ROCKEFELLER. Which is equivalent to?

Dr. WRIGHT. Which allows you to test a model or a very small segment of an actual structure. The Japanese use their very large shake table to put full-scale nuclear reactor vessels on the shake table, and use this documentation of their performance to sell these very high-value products in the Third World.

Senator ROCKEFELLER. Have you or any of the other witnesses at the table either made an effort to try and get us so that we have a shake table of that size, or requested the Japanese to use theirs for our purposes?

Dr. WRIGHT. We have collaborated with the Japanese in projects that use their shake tables, and we have conducted studies here in the United States of the potential for a large scale structural testing facility in the United States.

Senator ROCKEFELLER. That was so smooth, I did not hear it. In other words?

Dr. WRIGHT. We have studied for the potential of these facilities. However, there has not been an effort to provide major funding for them, to date.

Senator ROCKEFELLER. Well, have we gone over there?

Dr. WRIGHT. Yes, we have.

Senator ROCKEFELLER. And what have we taken with to put on those shake tables?

Dr. WRIGHT. Good. Let me mention a couple of the major collaborative activities, which includes this aspect. The most important thing——

Senator ROCKEFELLER. Let me ask you something. Are they in advance of us generally? I mean, I would assume so.

Dr. WRIGHT. They are very close to us in every area and advanced in some areas. We feel we are stronger in areas of modeling the dynamic performance of structures, but the Japanese certainly have better research testing facilities than we do. I will let my colleagues from the Geological Survey speak to the comparison of our work on the earth sciences.

Senator ROCKEFELLER. Or what it is. I do not necessarily have to have a comparison. I would like to know what it is, how we reach out to the international community and use what they have learned for our purposes?

Dr. EATON. Let me make some general remarks, Mr. Chairman, and then ask Dr. Robert Wesson, who has joined me here at the table, to comment if he wishes to.

The whole field of seismology has, from the very beginning, been an international effort because earthquakes know no particular continent, and understanding the Earth has required knowledge that has come from earthquakes that have occurred all around the globe. The Japanese, because of the currents of very devastating earthquakes and loss of life in their frequency, got off to an early start in the early part of this century in recording earthquakes instrumentally, and we copied, in the first and second decade, much of what they did.

We have come a very long way ourselves now and, I think because of the very international nature of the occurrence of earthquakes and the study of earthquakes and the operation of a worldwide instrument network, have stayed in touch, on the earth science side, with what is going on elsewhere in the world for a very long time.

Dr. Wesson, do you want to add anything to that?

Dr. WESSON. I might just add, Mr. Chairman, on the earth science side that we, too, are in very close collaboration with our Japanese colleagues, both through the U.S.-Japan Panel on Earthquake Prediction Technology and through some other mechanisms.

There is a somewhat different strategy in Japan toward reducing earthquake hazards than in the United States. The Japanese have placed somewhat higher emphasis on earthquake prediction than

we have. We shared that enthusiasm in the late 1970's, but have been increasingly awed by the difficulties in making short-term earthquake predictions and have shifted our emphasis somewhat more toward longer range activities. The Japanese have done that to some extent but have continued a very strong emphasis on earthquake prediction.

Senator ROCKEFELLER. How do you four, in fact, coordinate and set priorities? You all have different areas of this. U.S. Government agencies are not famous for coordinating well, and I assume you break the mold. I would like to know how you do it, what you do. This is a mammoth subject, and I am glad to know about ABC. I will be watching that. It is a mammoth subject. Americans are famous for never reacting until after the catastrophe, whether it is—you know, not just earthquake policy but almost any kind of policy. Now, how do you four coordinate?

Mr. MOORE. I think a lot of it is communication between the staff people who actually are in charge of implementing the programs and overseeing the various research projects; that I think we have enjoyed over the last several years a good relationship, both on a personal level and a professional level and it is really through regular meetings and sharing of the resources.

Senator ROCKEFELLER. But you are answering the process of coordination. I am asking partly that, but I am also asking how do you prioritize as a result of that process of coordination. You have got a small amount of money. I mean, generally speaking, how do you decide what your priorities are going to be?

Dr. WRIGHT. Can I try and answer that, sir?

Senator ROCKEFELLER. Why not?

Dr. WRIGHT. When the Northridge earthquake occurred we recognized it would be a very important opportunity there to investigate both earth science and engineering effects. So, we pulled together the career level leaders of the four agencies to identify the opportunities to learn from the earthquake and to assist in the earthquake response. We got an indication from the lead agency of the amount of funding that could be made available in the supplemental appropriation, and we went through a series of about five or six meetings bringing forth our ideas and then beating out our priorities so that we could assure that the funds were used for the most important topics.

Senator ROCKEFELLER. And what are they?

Dr. WRIGHT. They included the efforts at earth science research, the efforts at earthquake engineering research, the efforts to improve our instruments for measuring ground motions, and efforts to improve our design criteria for the various types of structures.

Mr. MOORE. The other is through the Building Seismic Safety Council we worked with the user community, too, quite extensively with the engineers and the architects and the people that are at the building end of the activity in the community to find out what their needs are and how they can best utilize the research that a number of the agencies support.

Senator ROCKEFELLER. Use, Mr. Moore, not utilize. That is the only area where I grow testy. Otherwise, I am a very gentle fellow.

Dr. Wright, could you repeat those priorities once again for me?

Dr. WRIGHT. The priorities include earth sciences, to understand earthquake mechanisms from the records developed in the earthquake, to understand such things as the effects of overburdened soil and topography on the intensity of motions that we must design our structures for, to understand how the structures behaved in the earthquake so that we can better predict performance in future earthquakes and make sure that new structures are strong enough and existing structures are assessed and strengthened to be strong enough, and we are working on developing design criteria for both new structures and existing structures to improve their earthquake resistance.

Senator ROCKEFELLER. Now, Senator Burns comes from Montana and I come from West Virginia, and somebody—Senator Kerry if he were here, comes from Massachusetts. What are you doing, and there are 38 States that are within the so-called area, and certainly—I do not know, is Massachusetts in that area?

Dr. WRIGHT. Massachusetts is in a seismic hazard area.

Senator ROCKEFELLER. How do you get out to these other States? How do you do it, how long have you been doing it, what are the results that Senator Burns and I can expect to see from that should there be an earthquake, and since you are within a budget restriction I assume that your answers are not going to be spectacular, and so I want you just to be honest with me.

Dr. WRIGHT. Let me answer it on the subject of building standards for seismically safe buildings. With the National Science Foundation and with the Federal Emergency Management Agency, we worked beginning in the 1970's to compile our current knowledge and put it in the form of building code provisions, provisions that could be adopted and enforced in all parts of the country. In other words, provisions that would be appropriate for the hazard in West Virginia and the hazard in Montana, the hazard in Massachusetts, not just the hazard in California.

We worked with the Building Seismic Safety Council, which Mr. Moore——

Senator ROCKEFELLER. I did not understand that. He said something that would be appropriate to Montana, West Virginia, not just to California. I do not understand what that means.

Dr. WRIGHT. Well, what we do is we assess with the aid of the Geological Survey the intensity of earthquake motions that we can expect in various parts of the country. And the earthquake you design for is not the same in California as it is in Massachusetts or West Virginia. The hazards are lower in West Virginia and in Massachusetts than they are in California. So, a building does not have to be as strong to be earthquake-safe.

Then we develop provisions suitable for building codes and standards which allow you to predict the strength of your building, whether it be masonry or timber or steel or concrete.

Senator ROCKEFELLER. Are there buildings in Montana using timber or concrete, steel or masonry, or in West Virginia or in Massachusetts, that have been built as a result of what you four together have done?

Dr. WRIGHT. Yes. Let me mention that. We develop these provisions to be nationally applicable. We then work with the model building code organizations. There are three major ones in the

United States: The International Conference of Building Officials serves the Western United States, the Building Officials Conference of America serves the Northeastern United States, and the Southern Building Code Congress serves the Southeastern United States.

We worked with these organizations to put the provisions in their model building codes, so they now are available for adoption by the States, the cities, and counties that provide the legal building codes. These provisions have been available now since 1992. It took a substantial amount of time.

You spoke of time. We began this effort in 1973, and in 1992 we have the up-to-date seismic provisions in the model codes that are used throughout the United States so that they are ready for adoption and enforcement by State and local governments. This is proceeding, though I would suspect if we checked the individual cities in Montana or in Missouri or in Massachusetts that not everyone has yet adopted and enforced those. But they are in the model codes that are in use in all 50 States.

Senator BURNS. I would like to ask just a small question here, begging the Senator's pardon.

Mr. Moore, I am probably the only one that serves in this Senate that worked with county-level FEMA people. As a commissioner, we worked very closely with our emergency people. In fact, the first time I ever had anything to do with you I sold I think 17 truckloads of crackers they had stored somewhere that went bad. I do not know. Auctioneers get to sell everything.

But let me tell you—or ask you that in Yellowstone County, MT, which is Billings, and that is the largest area in Montana with the highest density of population, we have adopted—our FEMA works with our contractors there and have got a computer data base that they use. Can you tell us about them? Are they fairly successful whenever they start going out and talking?

Now, I know NIST does some work, and Dr. Eaton at National Geological Survey, how successful that has been because we send our FEMA people back here to be reindoctrinated every now and again.

Mr. MOORE. It has had some success. We are doing a 3-year study right now with the National Institute of Building Sciences to improve upon that model to make it at least more predictable and more effective. But I think it has shown some promise, and that is why we are going forward with improving upon it and making sure that it matches with our geologic information system and other data that is now available.

Senator BURNS. Dr. Eaton, tell me, how do you pick out the areas where you have high potential of earthquakes?

Dr. EATON. The first cut at that is based on historical observations. We have been monitoring earthquakes for a very long time, and so the frequency of occurrence of events of various sizes is pretty well known across the whole of the United States.

Now, the sleeper in that is that, as I mentioned in my testimony, probably the greatest earthquake that has taken place since the European habitation of the United States was in the Lower Mississippi Valley which in the early part of the last century had a very, very low population. So, the concern is a combination of

where these earthquakes occur, how large they might be, or how frequent they might be, as in the case of southern California, and then whether or not these are areas that are occupied by large numbers of people and there is a substantial investment in infrastructure.

But our task among these four is to identify the areas where the seismic hazard is greatest and try to classify those in terms of national concern.

Senator BURNS. The earthquake you were talking about in the Lower Mississippi, was that New Madrid, MO?

Dr. EATON. Yes, it was.

Dr. WESSON. I might just add, Senator Burns, that we only have a few hundred years of actual history of earthquakes in the United States, since the European settlement of North America. But using geologic techniques, what we call paleoseismology, we are able to extend that record back on the order of 2,000 to 3,000 years in some parts of the country. And so in this way we can begin to build a longer record of the earthquakes that have occurred and predict or estimate more reliably what the hazard is across the country.

Senator BURNS. Mr. Moore, I understand in September of this year NEHRP is planning a large-scale earthquake exercise to test Montana's emergency management systems. Would you explain what that exercise will involve and what is expected that it will accomplish?

Mr. MOORE. Well, I would have to get back to you with some of the details on it, Senator, but basically what we would do in that sort of an exercise is to determine how the local and State agencies and the Federal Government would be prepared to respond if there were an earthquake event to make sure that we are talking to each other properly and effectively. We have to look at whether we have in place the kinds of code regulations that would strengthen the community to make sure that we are in a position to respond if there is significant damage, and to be prepared to work with the community, and with the States on a rebuilding or recovery effort to involve some mitigation and make the community stronger after the fact, and we will be looking at opportunities to provide that.

Senator BURNS. I do not have any more questions, Mr. Chairman.

Senator ROCKEFELLER. Well, let me ask one based upon something Dr. Eaton was saying, I think it was, with your permission, sir. We passed, several years ago—I forget what was the mountain range in Nevada where they are storing all of the nuclear waste.

Dr. EATON. Yucca Mountain.

Senator ROCKEFELLER. Now, that was very controversial, and I supported Harry Reid's filibuster—which eventually lost—because I had read that Yucca Mountain was a prime suspect for an earthquake. And I forget actually what happened and there has not been an earthquake there, but I assume that all four of you were called upon for your advice, were you not, by policymakers from the White House on this matter?

Dr. EATON. Let me ask—because I am just 8 weeks with the Geological Survey—let me ask Dr. Wesson to answer that question. It would have been before my time.

Dr. WESSON. Mr. Chairman, Geological Survey has participated with the Department of Energy in investigating the suitability of the Yucca Mountain site for the storage of high-level nuclear waste. There was, in fact, an earthquake called the Little Skull Mountain earthquake, which as I recall was about a magnitude 5 earthquake, about 20 or 30 miles south of Yucca Mountain a year and a half ago. So, there is some seismic hazard. There is some risk of earthquakes at Yucca Mountain.

Senator ROCKEFELLER. I am not asking for a description. I am asking for whether or not you were approached for policy advice, or if you were not whether you offered policy advice before this decision was made.

Dr. WESSON. Mr. Chairman, we continue to offer technical advice.

Senator ROCKEFELLER. To whom?

Dr. WESSON. To the Department of Energy, and we will to the Nuclear Regulatory Commission as the license processing proceeds.

Senator ROCKEFELLER. And in this case, what kind of advice did you offer them?

Dr. WESSON. We do our best to accurately describe the seismic hazard at the site, how strongly the ground will shake there, whether it would be subject to surface fault rupture and other kinds of earthquake hazards.

Senator ROCKEFELLER. But that is evasive. Did they listen to you? I mean, did anybody pursue?

Dr. WESSON. Yes, they continue to listen to us, Mr. Chairman. I think it is important to understand that there are—and I am not personally an expert on the engineered facilities to be built at Yucca Mountain, but the waste itself, as I understand it would be contained underground in conditions that are relatively insensitive to the strong shaking from earthquakes. But there would be facilities on the surface of the ground that would be more susceptible to shaking.

Senator ROCKEFELLER. Let me come at this a different way, then. You do not have very much money. Any of you, what is the total of what all of you spend? I do not need to know that. It is not a lot of money, we would all agree on that.

Dr. WRIGHT. It is about $100 million.

Senator ROCKEFELLER. You have got 38 States out there who are at risk. You do your best to get into their building codes. The advice which you offer them I assume to a certain extent they are putting your offerings into their building codes. Now, the three of you are shaking your heads, but they are all voluntary. If they go into the building codes that means they have to build according to those building codes, do the not? Then that is good news. So, out of the 38 States, do you have a sense of how many have accepted your advice on building codes?

Dr. WRIGHT. We did a survey of the States, or rather the National Conference of States on Building Codes and Standards surveyed its members to see where seismic provisions were adopted. This was done about 1990. It has not yet been updated to see how the recent provisions have been adopted, but I would be very happy to provide for your staff a copy of the report.

Senator ROCKEFELLER. I would be very happy to know that. That is a full 4½ years ago.

Dr. WRIGHT. It is becoming time to update the study.

Senator ROCKEFELLER. Do you know of anecdotal information? Have you heard about States that are using the seismic advice?

Dr. WRIGHT. For instance, the Memphis, TN, and Shelby County carried out a very strong debate just a few years ago about adopting seismic provisions and after some substantial opposition they did adopt and are now enforcing seismic provisions.

Senator ROCKEFELLER. Which means at what kind of buildings, office buildings, or all buildings?

Dr. WRIGHT. All types of buildings.

New York City is very seriously considering adopting seismic provisions in its code, but it has not yet done so. And New York State is considering the same provisions that New York City is.

Senator ROCKEFELLER. Do you know anything about my State?

Dr. WRIGHT. No, I do not, sir.

Senator ROCKEFELLER. West Virginia.

Dr. WRIGHT. I do not, sir.

Senator ROCKEFELLER. Could somebody supply information on me for that?

Dr. WRIGHT. Yes, we can.

Senator ROCKEFELLER. Who would best be able to do that?

Mr. MOORE. We could. We could, and we will work with the other agencies.

[The information referred to follows:]

Seismic provisions are adopted and enforced in West Virginia through the mandatory, statewide building code for West Virginia. Today, that code is based on the 1993 National Building Code, published by the Building Officials and Code Administrators International. It contains up-to-date seismic provisions, and its use has been endorsed by the Interagency Committee on Seismic Safety in Construction for enforcement of Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction."

The West Virginian State building code is enforced by local jurisdictions. The enclosed report, "Seismic Provisions of State and Local Building Codes and Their Enforcement," prepared for National Institute of Standards and Technology (NIST) by the National Conference of States on Building Codes and Standards, presents an overview of seismic code adoption and enforcement nationwide. This study, conducted in 1991, presents information on five West Virginia jurisdictions: Charleston, Parkersburg, Huntington, Beckley, and Bluefield. Only four West Virginia counties (McDowell, Mercer, Monroe, and Summers) are in a region of moderate seismicity; elsewhere the seismic hazard is considered low.

The U.S.-Japan Panel on Wind and Seismic Effects has provided an important mechanism for Japanese research and experience in earthquake hazard reduction. The enclosed paper, "Cooperation on Research and Technical Development in Wind and Earthquake Engineering Between U.S.A. and Japan in the Last 25 Years," is taken from the 1993 proceedings of the 25th Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects. Since this publication, the panel has continued active work holding seven more task committee workshops and its 26th joint meeting.

The paper describes many accomplishments. To highlight a few:

- Cooperative postearthquake investigations have allowed the United States to learn about earthquake mechanisms, side effects on ground shaking, soil stability, strucutural performance, and tsunami characteristics from Japanese experiences. U.S. seismic hazard maps and earthquake design criteria are based substantively on learning from Japanese earthquakes. U.S. models for predicting storm surge and tsunami effects have been improved and validated from measurements of Japanese storms and tsunamis.
- Cooperative testing, shared between U.S. and Japanese sites in laboratories, has led to: improved U.S. standards for assessing liquefaction potential of a site, and improved U.S. design standards for concrete, steel, and masonry building.

In response to the mandate from Congress and Public Law 101–614, ICSSC has been working on the preparation and implementation of standards for the seismic safety of existing federally owned or leased buildings. The enclosed report, "Standards of Seismic Safety for Existing Federally Owned or Leased Buildings and Commentary," presents the recently issued standards. The enclosed report, "Seismic Safety of Federal Buildings—Initial Program: How Much Will It Cost?" presents the proposed Executive order for preliminary implementation of the standards and estimates the cost of such implementation.

[The reports referred to may be found in the committee files.]

Senator ROCKEFELLER. In California, it is clear that every time they have an earthquake out there, there are more and more fault lines going in all directions, and we discover new ones. Is that atypical, as far as you know, of earthquake fault lines in this country?

Dr. EATON. I think it would be difficult to answer that question with any great assurance just based on the experience that we have been having.

In the case of the Northridge event, the hypocenter was on a fault that was not exposed to the surface. Now, the surface has been very heavily developed as a result of settlement in the area, and perhaps there were surface traces of these prior to the area being settled.

We do know that the whole of the southern California area, in the area of what is called the Big Bend in the San Andreas Fault, is one that is a great deal more complex in terms of the occurrence of faults of this kind.

There was a Whittier Narrows earthquake in the last decade that surprised us in the same way. We did not know of its existence. We came to know it only because of the earthquake. Now, that fault was very much of the same nature and origin as the one under Northridge.

So, yes, we are still learning things, a great deal of things, both in the earth science community and I think in the infrastructure community about each of these earthquakes as it occurs.

Senator ROCKEFELLER. Well, that again, as they occur. I mean, ideally one does not want to wait until an earthquake occurs, and so we come back again to small amounts of funding for agencies, communication between the four of you, trying to get as much as you can, learn as much as you can with the scarce resources that you have.

Let me ask this question in a different way. Let me just ask you four gentlemen. You or your counterparts, how many times a year do you get together?

Dr. EATON. Mr. Chairman, if I might, I cannot give you an answer to that specific question, but these other four gentlemen can. But I would like to share an impression I think that gets at this question and at your earlier question.

This is the first time I have met with any of these people other than Dr. Wesson. What impressed me is we all gathered in this room prior to the beginning of the hearing and prior to your entering, Mr. Chairman, was how well each of these people knew one another. In fact, I remarked on it three or four times.

They do get together, and they and their representatives get together often. And I think one of the reasons this program works as well as it does is that each of us has a very clear and a very

different responsibility, and yet our response collectively as representatives of the Federal Government depends on bringing each of these bits of knowledge and skills and responsibilities together in the program.

So, as someone who was recently an outsider, I want to share with you the fact that I regard this as a model program in terms of interbureau cooperation here. And my sense is that they and other representatives of each of their bureaus meet often enough really to have their arms around this program very well.

Senator ROCKEFELLER. Well, then let me ask each of you to give a simple description, a couple of sentences, of what your specific agency's responsibilities are with respect to this problem.

Mr. MOORE. Basically with regard to FEMA, the Federal Emergency Management Agency, part of it is working with the States. We provide a grant mechanism to the States and public information, education programs for the States to help them convince their folks that they should adopt and support and implement the building code regulations.

We work with the other agencies to glean from the research that they are providing and work with our user community, with the engineers and architects, to develop studies that will help us to make that information applicable to the people who build the buildings to make sure that they are complying with those codes. So, it is primarily a combination of transfer of the technology and coordination with the States.

If I may take this opportunity, with regard to West Virginia that you indicated an interest in earlier in the hearing, one of the concerns that we have with the State support and participation is that those States as they get to the fourth year, under the current act, are required to participate on a dollar-for-dollar match with the Federal Government.

It is becoming a difficult problem for some States, to be able to continue with the program. And it is contrary to what we are doing in other parts of FEMA with, for instance, the amendments that Congress enacted late last year with Stafford Act amendments that fund much of the disaster programs.

We have moved to a 75–25 match, and that has increased the participation by State and local governments. So, it is an area that I think needs to be looked at.

Senator ROCKEFELLER. Dr. Wright, your agency's participation.

Dr. WRIGHT. Yes. I would estimate for myself personally it is about 50 days per year that I am in face-to-face contact with people from one of the three other NEHRP Agencies. And if you consider my staff, it is probably a rare day in the year that there is not at least a telephone contact.

Senator ROCKEFELLER. And how would you describe your specific part of the responsibility?

Dr. WRIGHT. Our part is to provide problem-focused research and to make recommendations for the improvement of standards and practices for buildings and for lifelines.

Senator ROCKEFELLER. Not for water, gas, sewer. It is buildings.

Dr. WRIGHT. Those are lifelines. Lifelines are your transportation, communication, electrical power, water supply, sewage facilities.

Senator ROCKEFELLER. OK. Dr. Bordogna.

Dr. BORDOGNA. Our major task is to make sure the intellectual infrastructure of the country is very strong to address the cutting-edge issues here. We use most of our money to fund investigation of areas, determined among us, that need national attention.

We thus have a cadre of people across the country to make connections across all the States. The academic researchers and the earthquake engineers in practice and who are at the universities talk to each other frequently. They have conferences which we support.

This is one aspect of what we do—we keep the cutting edge rich, and we provide resources to people to keep moving the knowledge edge out based on the needs identified by this group primarily.

We also have two centers which have more formal responsibility to collect this information, integrate it, and promulgate it across the country, not just to individual investigators but in a holistic way.

We educate the researchers and practitioners. And we do both looking at why these things happen as well as how to mitigate against them.

There are also ancillary things going on that are not directly supported out of the $100 million. For example, NSF supports a large program in sensor technologies. You cannot really get at a smart way to investigate what is going on unless you can sense what is going on. So, there is a lot of work going on in electrical engineering and materials in developing sensors for these applications.

Senator ROCKEFELLER. Are you leaning on other countries' research for that, too?

Dr. BORDOGNA. Sure.

Senator ROCKEFELLER. Whose?

Dr. BORDOGNA. In fact the academic enterprise stretches across the whole globe, so when conferences are held and visitors come to NSF they come from all countries. Certainly, research connections with Japan and Europe are frequent.

Senator ROCKEFELLER. What are other countries particularly good at? Do certain countries do certain things particularly well?

Dr. BORDOGNA. I think Dick mentioned that they probably do better than we in the sense of investing more, particularly in the area of instrumentation, the large-scale instrumentation to do testing based on models that researchers develop. When we go to each earthquake and bring the data back, we improve the models about why things happen and why buildings fall down or roadways are disabled. And so we keep refining the model.

Incidentally, with regard to shake tables it is important not to jump at that kind of instrument because Japan does it one way and we should follow. We probably have more capability in taking shake tables and making them smarter, getting better data out of them and using simulation, for example.

So, NSF's part in all this—I want to emphasize again that I think the NEHRP group, whatever it has done, good or bad, in the past, it is essential to keep the agencies together on this. There must be a holistic view so we all can connect. And anything that can be done to enforce that connection, to enrich it, to nurture it,

coming from the Senate would be very, very helpful. We do not want this to split apart.

In summary, NSF's part in this activity is really usually on the cutting edge to face the needs on the research end, but based on needs defined by the group.

Senator ROCKEFELLER. And these requests for research grants come from whom?

Dr. BORDOGNA. Well, we send out announcements and the proposals come into NSF, and we conduct ave merit review. In fact we have, I think, 400 proposals now in for the most recent announcement.

Senator ROCKEFELLER. Where do they tend to come from?

Dr. BORDOGNA. From all over the country.

Senator ROCKEFELLER. I understand that. Universities or other——

Dr. BORDOGNA. Universities. Well, not-for-profit entities, but mostly universities. We also have people with earthquake interests on a national advisory committee in engineering, so there are connections there.

Most of our requests or proposals come in from universities.

Senator ROCKEFELLER. Any area that you gentlemen would like to see more activity in, more aggressiveness on our part? I mean, at least a couple of those overpasses that fell down were already upgraded, were they not, in the Northridge area?

Dr. WRIGHT. Of the overpasses that failed, none of them were designed in accord with the current specifications.

Senator ROCKEFELLER. Well then, if they had been, how would you know whether or not they would have failed unless you had a really smart shake table?

Dr. WRIGHT. There were a number of overpasses that had been designed according to modern specifications that performed well. There were a number that have been retrofitted according to modern knowledge gained since the Loma Prieta earthquake in 1989 that performed well. So, we got confirmation that was even better than a shake table, and that was a real earthquake.

Senator ROCKEFELLER. You know, my daughter graduated from Stanford University last year, and 4 years before that when she making the decision to go out there I spent an hour on the phone with, as it turns out to be, Vice President Gore's seismologist, or a person that he advised me was a really good seismologist, because I was what you call a concerned parent. And it was worth an hour of my time to find out whether or not—what their situation was.

And he basically said that there are always dangers anywhere in California, but that the north is far better prepared than the southern part of California, that they have done their infrastructure changes more. As it turned out, northern California did of course have that earthquake and there was about 200 million dollars' worth of damage on the Stanford campus but no lives were lost.

Now, what does FEMA do about that, not Stanford but the idea that within one State, all of which is well known for earthquakes, there can be an enormous variance, if the seismologist is correct, between the northern and southern part?

He ascribed it partly to cultural reasons, that southern Californians believe that, you know, life is eternal, nothing will ever happen, they are more optimistic. But what do you do about a situation like that?

Mr. MOORE. Well, we work with the States to try to convince them that the information that we provide them is something worthy of adoption in their codes and in their process. We cannot mandate that they do so under the Federal system, but we try to provide that information to their people to educate the population on what needs to be done and what their public officials could be doing to make their community safer, and what the public officials ought to do.

Senator ROCKEFELLER. So, you disseminate.

Mr. MOORE. Yes.

Senator ROCKEFELLER. Of the 38 States, in the judgment of the four of you independently, about how many of the 38 are taking your building and lifeline codes seriously?

Dr. WRIGHT. To comment on that, of course California is the leader in taking these seriously.

Senator ROCKEFELLER. I do not need to know the names.

Dr. WRIGHT. But one thing I want to note is that there are no national standards for lifelines. That is a deficiency in the program.

You mentioned earlier what things do we need to address, and one of the things we need to address is to provide nationally applicable standards for earthquake resistent lifelines.

Another thing we need to address are the problems of property loss and functionality in building because our current building code is intended to avoid collapse in a major earthquake, and we consider it a success if the building and its contents are a total loss as long as it did not collapse, because that was our objective. So, we need to develop criteria that are appropriate for use when reducing property damage and maintaining functionality are worthy of investment by the owner.

Senator ROCKEFELLER. That is interesting. So, in other words the building could stay but everything within it could be rattled all over, and it would a success.

Dr. WRIGHT. It is a success by the criteria that were established in the development of the code, because the purpose of the code was not to spend too much money, but to avoid large losses of life.

Mr. MOORE. One other thing we are doing with regard to mitigation is an area that is not really that expensive in the overall scheme of things, and that is that the contents of the building can be secured for a relatively nominal means. If they have a hot water heater or appliances they can be bolted down, bookshelves can be lined just as if you were on a boat so that you can counter that rocking effect and the disaster that occurs as a result.

And we are working in California with the schools, looking at the building structures. Most of the problems with the schools are with the ceiling tiles and the metal bars that fell down that could have caused problems. And so looking at some of the contents of the buildings is the next stage of transferring that information.

Senator ROCKEFELLER. So, let me get an answer on my 38. Is it more than one-half or less than one-half?

Dr. WRIGHT. Less than one-half are taking it really seriously.

Senator ROCKEFELLER. Are those areas like Memphis and Missouri—those that take it more seriously, do they correspond to the more serious areas?

Dr. WRIGHT. FEMA has had a great deal of success in the New Madrid area in establishing the central U.S. earthquake consortium which now represents I believe 10 States. And the emergency managers and the members of the consortium are taking it quite seriously, but to make this actually be adoption and enforcement of building standards by the individual municipalities, I think a lot of work is needed before it is normal that the buildings are designed and constructed for earthquakes.

Mr. MOORE. There are a number of States that do not yet have statewide building codes, not to mention seismic standards, but any standards. And some of it is left to the county or local level, or does not exist at all.

Senator ROCKEFELLER. Of the county or local level it will not work, right? In other words, the State has to push it.

Mr. MOORE. Well, a county could adopt standards that are considered to be successful in other areas without the State doing it, but it is better if it is done on a uniform basis. It provides better guidance to the architects and the contractors.

But I think of the States that you are talking about, the 38 States, they did not all enter the program at the same time. Probably about one-half of those States are in the first few years of participating and so they just really are beginning their programs.

The way the law has been drafted ever since the last reauthorization was that the first year of the program we provide through FEMA their full grant, and then we ease them out of that. But one of the concerns we have got is now that we have got about half of those States having had about 4 years in the program and some of them facing some budgetary problems, as we all seem to be facing these days, there is some concern whether they are going to be able to continue participating in the program and sharing that information, rather then sit back and wait for a disaster and then be bailed out completely by the Federal Government.

Senator ROCKEFELLER. Speaking of budgetary constraints, within your own agencies, four agencies, you are all facing FTE cuts; right?

To the extent that you know, will these affect your work disproportionately more than other parts? And I do not even know how to ask the question, but you know what I am asking.

Dr. EATON. In the case of the Geological Survey, I think the impact is essentially transparent. The FTE ceiling is not having a significant impact in this particular programmatic area.

Dr. BORDOGNA. It has not affected NSF in this area.

Dr. WRIGHT. NIST is fortunate in not receiving FTE cuts.

Senator ROCKEFELLER. Oh, yes you are.

Mr. MOORE. FEMA has not received cuts in the fiscal year 1995 request. In fact, the administration has recommended some modest increase in FTE, and part of that is in the earthquake program in response to some of the demand that we faced over the last year or two.

Senator ROCKEFELLER. I am just interested, and then I am going to close this hearing, but do any of you know that every U.S. Sen-

ator is cutting his or her Senate budget in their own office by 25 percent? Did any of you know that?

Dr. WRIGHT. I did not.

Dr. BORDOGNA. No.

Senator ROCKEFELLER. On that note I thank you very, very much, and I really do. This is new to me and I have got to learn more through some questions that I have that I did not ask. You will get them.

It was very, very useful to me, and I really enjoyed the interchange with all of you. I think it was a productive hearing.

Thank you very much.

[Whereupon, at 3:55 p.m., the hearing was adjourned.]

# APPENDIX

## Prepared Statement of Senator Pressler

Let me begin by thanking the chairman for calling this very important hearing on the reauthorization of the National Earthquake Hazards Reduction Program—NEHRP.

The NEHRP can offer some very necessary services not only to areas prone to earthquakes, but to the entire Nation. Although my home State of South Dakota experiences few earthquakes, the people of South Dakota—as well as the entire Nation—are too often held responsible for the great expense caused by these disasters. In the last 5 years alone, Federal relief efforts for the Loma Prieta and Northridge earthquakes have cost taxpayers billions of dollars.

For this reason, the NEHRP must continue to work for more accurate predictions of fault line activity, stricter building codes, proper land management, and improved building construction.

Before approving reauthorization legislation, we should first determine the effectiveness of this interagency program. I hope that today's witnesses will inform us as to how the NEHRP has been able to assist planning and preparedness for areas hit by earthquakes, as well as provide us with their views and plans to further advance their goals.

Thank you, again, Mr. Chairman, for calling this hearing. I welcome the witnesses and look forward to hearing their testimony.

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## Questions Asked by Senator Rockefeller and Answers Thereto by Mr. Moore

*Question.* Four Federal agencies participate actively in the earthquake program. How are annual budgets determined and performance milestones coordinated among the four agencies?

Answer. Annual budgets are prepared from several foundations. First, through a variety of mechanisms, such as workshops and conferences, the earthquake user community communicates its needs. With them in mind, FEMA's budget requests are developed in line with the Agencies' program responsibilities under the Earthquake Hazards Reduction Act. In order to address the chance that some each of the Agencies' planned activities in a fiscal year may duplicate or be more complementarily formulated, the National Earthquake Hazards Reduction Program (NEHRP) agencies discuss and collaborate on their respective budget submissions using the Interagency Coordinating Committee (ICC). Performance milestones are then based on the execution of these budget requests and, again, are coordinated among the NEHRP Agencies through the ICC.

*Question.* What are the priorities for the current earthquake program?

Answer. Priorities for the current earthquake program are determined by each agency based on their individual authorities and responsibilities as set forth under the Earthquake Hazard Reduction Act. Several processes have aided in coordination of the Agencies' independent formulation, such as the development of the NEHRP Five Year Plan, and a strategic planning process undertaken in 1993. This system of coordinating priorities has resulted, for example, in the establishment of the program's structure, and the planning of programmatic activities for each of the Agencies under this structure. A copy of the most recent five year plan is enclosed for your information and reference.

*Question.* The Northridge earthquake has proven that technologies developed under the earthquake program are successful in mitigating damage. Please describe the process of identifying and pursuing priority technologies among the four agencies for the earthquake program.

Answer. In concert with the other principal NEHRP agencies, FEMA continues to work with all constituencies within the earthquake community. This collaboration

both formal and informal, and provides the Agencies with the user communities' identified priority needs. Their problems are our challenges. The Agencies' develop programmatic or research oriented solutions to these priority needs in their budgetary planning cycles. Through investigations, studies, research or program development and delivery actions that focus on the user communities problems, NEHRP pursues the most promising and priority technologies and techniques for earthquake risk reduction.

*Question.* The President's fiscal year (FY) 1995 budget of $103.2 million for the earthquake program requests a $3.6 million increase over this year's spending levels. H.R. 3485, passed last year, authorizes the program at $102.7 million for FY 1995 or $3.1 million increase. For a difference of $500,000 between the President's request and the House-passed bill, what agencies and activities will be affected?

Answer. The President's request for Fiscal Year (FY) 1995 includes $25,001,000 for the Federal Emergency Management Agency's activities under NEHRP. H.R. 3485 authorizes $20,805,000 for the Agency. The difference reflects the enhancement to FEMA's earthquake risk reduction activities that the President is pursuing for FY 1995. These enhancements are for increased funding support for ongoing State and local earthquake risk reduction activities; the conduct of studies that will improve the NEHRP Recommended Provisions for New Buildings; and support for the development of pilot and demonstration projects centered on the development and provision of mitigation incentives to state and local governments.

*Question.* H.R. 3485 contains several "Buy America" requirements which were not provided in previous earthquake program reauthorizations. Will any of these provisions change the way the Federal agencies undertake their work on the earthquake program?

Answer. The "Buy America" requirements will have no affect on FEMA's implementation of its NEHRP responsibilities.

*Question.* Electrical, gas, and water lines and communications are critical to battle secondary effects of earthquakes such as fire. What technologies have been developed under the earthquake program to protect these community "lifelines" from earthquake damage?

Answer. The U.S. Geological Survey, National Science Foundation and National Institute of Standards and Technology have each performed research, within their program specific responsibilities, that address the seismic vulnerability of our Nation's system of lifelines. Additionally, the Federal Emergency Management Agency, in consultation with NIST, is completing a "Plan for Developing and Adopting Seismic Design Guidelines and Standards for Lifelines." Implementation of the Plan will further protect community lifelines systems (i.e., electric power, gas and liquid fuel, telecommunication, transportation, and water and sewer) from earthquake damage.

*Question.* FEMA is the lead agency for the earthquake program and is responsible for disseminating information on earthquake preparedness. Please describe how FEMA provides information on hazard mitigation technologies developed under the earthquake program to the 38 states which have a significant seismic risk.

Answer. Hazard mitigation technology transfer is conducted directly by FEMA:

- A variety of hazard mitigation technology courses are available through FEMA'S Emergency Management Institute (EMI). For example, EMI offers Earthquake Hazard Mitigation for Utility Lifeline Systems, and Earthquake and Fire Hazards in High-Rise Buildings as both resident and field delivered courses;
- FEMA supports the Building Seismic Safety Commission (BSSC) to conduct outreach and seminars, provide speakers and disseminate FEMA/BSSC publications to encourage application and enforcement of seismic safety provisions in new construction; and
- FEMA also provides a speakers bureau and disseminates FEMA products on seismic rehabilitation of existing buildings to encourage application of seismic rehabilitation measures.

FEMA also collaborates with other organizations in the transfer of earthquake risk deduction knowledge and technology. In particular, FEMA supports a number of other organizations, such as the National Center for Earthquake Engineering Research, Southern California Earthquake Center, Earthquake Engineering Research Institute, Central United States Earthquake Consortium and the Natural Hazards Research Applications Center to provide publications, information, training and education on hazard mitigation technologies.

*Question.* $15 million was appropriated to FEMA for the earthquake program under the emergency supplemental act earlier this year. Please describe what additional activities are being done and how this money has been distributed among the other Federal agencies.

Answer. FEMA, in close coordination with the other three NEHRP agencies, identified the amounts to be distributed to each of the NEHRP Agencies for studying

and investigating the causes and effects of the Northridge earthquake. The National Science Foundation, acting for the four agencies together, issued a request for proposals from the non-federal community based NEHRP identified informational opportunities presented by the Northridge event. FEMA, USGS and NIST undertook to conduct specially-focussed, needs-driven investigations and studies with a portion of the funds. The distribution is as follows: USGS, $4M; FEMA, $2.5M; NIST, $1.5M; and NSF, $7M (for NEHRP wide studies). Results of the studies will be delivered to the NEHRP user community through conferences, publications, symposia and other appropriate mechanisms.

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QUESTIONS ASKED BY SENATOR ROCKEFELLER AND ANSWERS THERETO BY DR. EATON

*Question.* Four Federal agencies participate actively in the earthquake program. How are annual budgets determined and performance milestones coordinated among the four agencies?

Answer. Each of the four principal agencies under NEHRP develops its own budget according to its responsibilities under the Act. Discussions about budgets are held among the NEHRP agencies through the Interagency Coordinating Committee. Each year the four agencies meet to develop an annual budget report which is submitted by FEMA's Office of Earthquakes and Natural Hazards to OMB.

*Question.* What are the priorities for the current earthquake program?

Answer. The priorities for the current earthquake program are found in the Five Year Plan for 1992–96 and in a draft Strategic Plan developed by the four agencies in 1993. These priorities include:

- understand why and how earthquakes occur in order to provide a firm basis of scientific understanding for developing effective and reliable hazard reduction measures;
- define and characterize potential earthquake sources and source regions, determine rates of seismic activity, establish the state of each source within its earthquake cycle, and document, model, and predict earthquake effects, in order to identify areas and populations at greater risk;
- make the behavior of buildings and lifelines predictable, including earthquake effects on occupants and contents;
- understand the social, economic and institutional dimensions of earthquake hazards in order to facilitate more effective mitigation, preparedness and response actions in communities across the U.S.;
- develop and implement practices for the safe and functional performance of buildings and lifelines;
- develop and implement practices for responsible societal and individual responses to earthquake hazards and occurrences; and
- develop and implement practices for controlling secondary losses and stimulating recovery from damaging earthquakes.

*Question.* The Northridge earthquake has proven that technologies developed under the earthquake program are successful in mitigating damage. Please describe the process of identifying and pursuing priority technologies among the four agencies for the earthquake program.

Answer. Each agency uses strategic planning, workshops and interaction with the public to identify and pursue priority technologies. The Interagency Coordinating Committee is a vehicle for discussing these technologies.

*Question.* The President's fiscal year (FY) 1995 budget of $103.2 million for the earthquake program requests a $3.6 million increase over this year's spending levels. H.R. 3485, passed last year, authorizes the program at $102.7 million for FY 1995 or $3.1 million increase. For a difference of $500,000 between the President's request and the House-passed bill, what agencies and activities will be affected?

Answer. FEMA's earthquake risk reduction activities will be enhanced in the area of ongoing State and local earthquake risk reduction activities, the conduct of studies to improve the NEHRP Recommended Provisions for New Buildings, and support for the development and provision of mitigation incentives to State and local governments. The House-passed bill authorizes the NIST budget at its current level. The unavailability of the President's proposed increase would curtail NIST's research and development efforts in the area of lifeline earthquake engineering. For the NSF Engineering and Geosciences Directorates, H.R. 3485 authorizes an increase above the President's 1995 request. The effect, if any, will enhance currently planned activities. The USGS budget would remain at the current level. The impact will be accommodated by either reducing the scope of selected studies or increasing the time to complete them.

*Question.* H.R. 3485 contains several "Buy America" requirements which were not provided in previous earthquake program reauthorizations. Will any of these provisions change the way the Federal agencies undertake their work in the earthquake program?

Answer. No. These provisions will have little or no impact on the way the USGS undertakes its work in the earthquake program, and to the best of our knowledge will have little or no impact on the other participating agencies.

*Question.* Electrical, gas and water lines and communication are critical to battle secondary effects of earthquakes, such as fire. What technologies have been developed under the earthquake program to protect these community "lifelines" from earthquake damage?

Answer. The USGS places strong emphasis on documenting the effects of moderate to large earthquakes as they occur, as well as estimating the effects that could result from future earthquakes in specific regions. The results of these efforts can be used in specifying the ground motion predictions for engineering design and in assessing the potential for ground failure under postulated earthquake conditions. The USGS produces seismic zonation maps at scales which can relate potential site effects to the location of electrical, gas, water lines and communication systems. This information can be of use in the retrofitting of existing structures or in the design of new ones.

*Question.* The Northridge earthquake revealed that the Los Angeles area may lie on a complex set of thrust faults. Is the Los Angeles area unique in this regard? How does an area like Los Angeles prepare for earthquakes in the future?

Answer. The Los Angeles area is not unique in terms of its faulting environment. Thrust faults of a similar nature occur in sedimentary basins elsewhere. The 1993 Coalinga earthquake and the 1987 Whittier Narrow earthquake occurred on similar structures. Although specific buried thrust faults are more difficult to identify and characterize than faults exposed at the surface, it is generally possible to identity broad regions that are subject to these hazards.

In order for an area like Los Angeles to prepare for earthquakes in the future, there is a need to anticipate the hazard, assess the risk, and mitigate potential losses rather than just responding to disasters. Disaster reduction involves careful land use planning, sound engineering practice, enforcement of adequate building codes to ensure resiliency of lifelines and other infrastructures, and effective emergency preparedness and response.

*Question.* An original purpose of the Earthquake Hazards Reduction Act of 1977 was to predict earthquakes. Today, are we any closer to predicting earthquakes?

Answer. Short-term earthquake prediction has not been attained. Great progress, however, has been made in identifying and characterizing future earthquake potential in probabilistic terms. In addition, significant progress has been made in developing methods to estimate the geographic effects of earthquake-related hazards (landslides, liquefaction, and strong shaking) in probabilistic terms. The combination of the probability of future earthquake events and their effects provides the fundamental elements of a decision-oriented loss reduction strategy. Quantitative estimates of the strong ground motions to be expected at specific sites from future earthquakes are proving possible. The USGS is continuing an earthquake prediction experiment at Parkfield, California.

*Question.* What kinds of earthquake risks do eastern states like West Virginia face?

Answer. Although West Virginia and a number of other states along the eastern seaboard have much lower annual risks from earthquakes than California and other states along the margin of the North American tectonic plate, their risks are not zero. If we use the historical record of earthquake activity as a guide, the most likely threat to West Virginia would be a recurrence of the moderate magnitude 6.3 Giles County, Virginia, earthquake of May 31, 1897. Today, the primary risks would be to old unreinforced masonry buildings, new buildings and bridges built since 1897 which might vibrate in tune with the underlying soils, and underground pipelines which might be subjected to permanent ground displacement induced by the ground shaking. Potential vulnerabilities such as these have been exposed repeatedly throughout the United States and abroad in moderate-magnitude earthquakes. The technology exists to assess these potential threats.

QUESTIONS ASKED BY SENATOR ROCKEFELLER AND ANSWERS THERETO BY DR. WRIGHT

*Question.* Four Federal agencies participate actively in the earthquake program. How are annual budgets determined and performance milestones coordinated among the four agencies?

Answer. Annual budget requests and performance milestones are determined and coordinated through the NEHRP Interagency Coordinating Committee (ICC), whose members are senior line managers of the NEHRP agencies. The ICC provides program-level direction in the preparation of the consolidated NEHRP budget and its presentation to the Office of Management and Budget, the development of the NEHRP Five Year Plan, and the preparation of NEHRP strategic plans. The most recent Five Year Plan, which was published in September 1991, covers the period from 1992 to 1996. Annual budgets and performance milestones are developed by the individual agencies to implement the Five Year Plan. Moreover, following the January 1994 Northridge earthquake, the ICC held a number of meetings to develop an integrated approach for proposing and implementing the $15M supplemental funding for earthquake studies.

In January 1993, the ICC prepared a draft strategic plan. The draft strategic plan is the basis for ongoing planning of NEHRP and an input to the National Earthquake Strategy Working Group of the President's Office of Science and Technology Policy.

*Question.* What are the priorities for the current earthquake program?

Answer. There are seven priorities in the current NEHRP program, as listed in the program's Five-Year Plan for 1992-1996. They are:

Fundamental Earthquake Studies; Earthquake Hazard Potential; Earthquake Effects and Engineering Research; Planning for and Mitigating Earthquakes; Information Systems and Dissemination; Postearthquake Studies; and International Cooperation.

*Question.* The Northridge earthquake has proven that technologies developed under the earthquake program are successful in mitigating damage. Please describe the process of identifying and pursuing priority technologies among the four agencies for the earthquake program.

Answer. Identification of priorities occurs at the ICC level, during strategic planning and formulation of Five Year Plans and through ongoing reviews or program efforts. The responsibility for pursuing the identified priorities rests with each agency, based on its level of appropriations.

NIST, in fulfilling its assigned role in NEHRP, research and development to improve standards for buildings and lifelines, identifies and pursues priority technologies based on user needs. NIST maintains close contacts with such private sector prestandardization organizations as the Building Seismic Safety Council (BSSC) and the Applied Technology Council. NIST staff members are active participants in workshops and conferences organized by NSF, FEMA, and USGS, and the Earthquake Engineering Research Institute (EERI). NIST maintains close contacts with code setting bodies and developers of standards, such as ICBO (Uniform Building Code), BOCA (National Building Code), SBCCI (Standard Building Code), American Society for Testing and Materials (ASTM), American Society of Civil Engineers (ASCE), American Concrete Institute (ACI), and American Institute of Steel Construction (AISC). Post-earthquake reconnaissance efforts allow NIST researchers to identify technical issues that need to be addressed for improved seismic safety. NIST remains in close touch with the needs of the Federal community through the Interagency Committee on Seismic Safety in Construction (ICSSC), which NIST chairs and administers. Through the ICSSC, 31 Federal agencies concerned with seismic safety collaborate to develop earthquake hazard reduction measures suitable for incorporation into Federal agency programs.

*Question.* The President's fiscal year (FY) 1995 budget of $103.2 million for the earthquake program requests a $3.6 million increase over this year's spending levels. H.R. 3485, passed last year, authorizes the program at $102.7 million for FY 1995 or $3.1 million increase. For a difference of $500,000 between the President's request and the House-passed bill. what agencies and activities will be affected?

Answer. Of the President's FY 1995 budget request of $103.2 million for the earthquake program, $1.932 million was for NIST. The House-passed bill authorizes the NIST earthquake budget at $1.532 million, a $400,000 decrease from the President's request. The unavailability of the President's proposed increase would curtail NIST's research and development efforts in the area of lifeline earthquake engineering. Specifically, NIST would cot be able to conduct a demonstration project, working with the Electric Power Research Institute (EPRI), a power industry consortium,

that would lead to the development of seismic safety guidelines (prestandards) for the electric power lifelines.

*Question.* H.R. 3485 contain several "Buy America" requirements which were not provided in previous earthquake program reauthorizations. Will any of these provisions change the way the Federal agencies undertake their work in the earthquake program?

Answer. These provisions have a minimal effect on NIST's earthquake engineering program. NIST's main effort is in-house R&D utilizing existing testing facilities. NIST buys scientific instruments from U.S. companies. NIST's NEHRP collaboration with experts in other countries, such as Japan, is limited to exchanging information, jointly supporting workshops and conferences, and exchanging guest researchers.

*Question.* Electrical, gas, and water lines and communications are critical to battle secondary effects of earthquakes such fire. What technologies have been developed under the earthquake program to protect these community "lifelines" from earthquake damage?

Answer. Research by NSF, USGS and NIST on earthquake hazards and the response of structures to earthquakes has been applicable to both building and lifeline structures. As the need for efforts more specifically focused on lifelines has become apparent, NSF and NIST have supported lifeline-specific projects. For example, NIST recently issued a report on estimating liquefaction potential at lifeline sites.

Congress, in the 1990 NEHRP Reauthorization Act (Public Law 101–614), recognized the importance of maintaining the functionality of lifelines during and after an earthquake and the lack of nationally accepted design guidelines in any lifeline area other than transportation, by mandating FEMA, in consultation with NIST, to develop "a plan, including precise timetables and budget estimates, for developing and adopting, in consultation with appropriate private sector organizations, design and construction standards for lifelines" and "recommendations of ways Federal regulatory authority could be used to expedite the implementation of such standards."

In response to this mandate, FEMA and NIST, working with appropriate private sector organizations and the NEHRP Advisory Committee, developed the plan. The plan focuses on drafting guidelines based on available knowledge, testing and improving them in demonstration projects, supporting the adoption of these guidelines by the standards and professional organizations serving the lifeline community, and working with the lifeline community to achieve effective implementation. Since lifelines are long-lived and regularly maintained, the plan emphasizes the assessment and mitigation of hazards to existing lifelines. The Plan calls for NSF, USGS and NIST to respond through their research programs to knowledge needs identified in the standards development process.

*Question.* What are the primary reasons why states would not incorporate requirements for hazard mitigation technologies into their building codes?

Answer. In general, states, which have a statewide building code, adopt the provisions of one of the three model building codes. These states generally update their code regularly, usually on a three- or four-year cycle, again based on a model code which is updated annually.

However, as of 1992, only half of the states had a mandatory statewide code with seismic provisions. For states without a statewide code, the adoption of building codes is left to local or county jurisdictions. Many counties, cities and towns within these states have adopted a building code with adequate seismic provisions.

NIST has made no recent study of reasons why states do not adopt statewide building codes. Reasons may include adversity to regulations and tradition to delegate the building regulatory responsibility to local governments. In some instances, particularly in smaller communities, jurisdictions may minimize their regulatory activities, which can lead to obsolete local codes, failure to enforce codes, and even failure to adopt any code at all.

*Question.* Please describe recommendations for increasing the transfer of hazard mitigation technologies from the earthquake program to states and the construction industry.

Answer. Users, such as owners, designers, builders, regulators and suppliers, should play a principal role in problem focused research and financial and technical support for these technology transfer activities. In cooperation with the private sector, NEHRP should continue and strengthen efforts to evaluate, synthesize, and translate new technologies into design and construction practices, by packaging synthesized knowledge into formats (such as design manuals) that can be readily used by practitioners. NEHRP should continue and strengthen its technical support to model code bodies and encourage them to adopt updated design guidelines into their model code documents. NEHRP should support the model code organizations' efforts to work with state and local governments to promote the adoption of model codes in state and local regulations and their enforcement. NEHRP should track proposed

changes to the model codes to support those that would improve risk reduction and oppose those that would increase risks.

NIST's role in NEHRP, research and development for improvement of standards for buildings and lifelines, suggests that NIST should play a principal role in problem focused research and financial and technical support for these technology transfer activities.

Finally, note that enhanced technology transfer will lead to stronger demands for knowledge needed to fill gaps identified in the development and use of risk reduction practices.

*Question.* Earthciuakes are not unique to the United States. Please describe any benefits and costs resulting from collaborations on earthquake technologies with other countries.

Answer. There are many benefits when earthquake-prone countries work closely together to share information and experiences related to earthquake hazard reduction. International cooperation can speed up the development of key data bases, such as collections of strong ground motion records and evaluations of the actual performance of structures equipped with new and developing technologies, such as structural control systems. Good examples are the establishment of two sophisticated arrays of strong ground motion recorders in Taiwan, one of the most seismically active areas of the world, under a multi-national financial and technical support agreement between the U.S., Japan, Taiwan, and Korea; Japanese arrays whose results are available to the U.S. through the U.S.-Japan Panel on Wind and Seismic Effects; and the cooperative structural research conducted under the U.S.-Japan Panel on Wind and Seismic Effects.

International collaboration allows the U.S. to learn from foreign earthquakes through collaborative post-earthquake investigations. Such investigations provide opportunities to collect perishable data, assess how current technologies performed during a real event, and learn lessons that can be used immediately to guide NEHRP's R&D program and provide advances in seismic safety practices.

Joint international projects make large-scale field and laboratory experiments possible. Such experiments often are too costly for a single country to undertake. With proper planning and carefully execution, the results of the efforts will be directly useful to all the sponsoring countries.

NEHRP has gained greatly from international collaboration since the program's inception in 1977. An outstanding example of such collaboration is the U.S.-Japan Panel on Wind and Seismic Effects, a component of the U.S.-Japan Program in Natural Resources. The Panel allows researchers and practitioners of both countries to exchange technical data, collaborate on experimental work including large-scale testing, jointly participate in post-earthquake investigations, and exchange technical personnel. The panel just completed its 26th annual meeting in May 1994. NIST provides the chair and secretariat for the U.S. side of the Panel.

Costs for international collaboration are generally quite modest -usually the only extra cost is travel needed to access the work of foreign investigators or to observe or participate in foreign investigations.

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QUESTIONS ASKED BY SENATOR ROCKEFELLER AND ANSWERS THERETO BY MR. BORDOGNA

*Question.* Four agencies participate actively in the earthquake program. How are annual budgets determined and performance milestones coordinated among the four agencies?

Answer. The annual budget process and development of performance milestones are influenced mainly by the National Earthquake Hazards Reduction Program (NEHRP) Five-Year Plan. The four NEHRP agencies have developed a series of five-year plans to establish priorities and coordinate efforts among the agencies. Input to the development of the five-year plan is derived from legislation, advisory committees, agency management, and agency coordination meetings, especially those held by the Interagency Coordination Committee. The latest five-year plan covers the period of 1992-1996. The next plan, normally due this year, is being delayed awaiting input from the current OSTP and OTA reviews of the NEHRP program.

A coordinated NEHRP budget is prepared annually and submitted to OMB. The NEHRP budget levels for each agency are based on the role played in the program, as defined in the five-year plan, and on priorities set within each agency.

*Question.* What are the priorities for the current earthquake program?

Answer. The priorities for NSF in the current earthquake program are as defined in the current NEHRP Five-Year Plan. The elements of that plan are A) NEHRP Leadership, B) Fundamental Earthquake Studies, C) Earthquake Hazard Potential,

D) Earthquake Effects and Engineering Research, E) Planning for Mitigating Earthquakes, F) Information Systems and Dissemination, G) Postearthquake Studies, and H) International Cooperation. NSF responsibilities are concentrated in elements B, D, F, G, and H.

Special priorities were set for the Northridge earthquake by the NEHRP Interagency Coordination Committee pursuant to the emergency supplemental appropriation, PL 103-211. These priorities are A) Actively influencing recovery, reconstruction, and mitigation, B) Learning the lessons of the Northridge earthquake in the hazard environment area, C) Learning the lessons of the Northridge earthquake regarding the built environment, D) Learning the lessons of the earthquake in the socioeconomic area, and F) Applying the lessons of the earthquake to advance mitigation.

*Question.* The Northridge earthquake has proven that technologies developed under the earthquake program are successful in mitigating damage. Please describe the process of identifying and pursuing priority technologies among the four agencies for the earthquake program.

Answer. The Northridge earthquake experience provides a good example of how the tour agencies pursue priority technologies in the context of the NEHRP five-year plan. Discussions were held on the day of the earthquake to determine the NEHRP approach for the collection of perishable information, including data on the performance of technologies in place at the time of the event. This was followed by a series of joint planning meetings for reaching consensus on the long-term investigations and related activities that the NEHRP agencies would pursue. One result was the external NEHRP Northridge earthquake research program, which focuses on understanding the hazard environment, the built environment, and the societal environment in relation to the earthquake. Over 400 proposals have been received and evaluated by the NEHRP agencies with the help of expert review panels and subsequent awards will lead to new mitigation technologies and the modification of existing ones.

NSF and the other NEHRP agencies work very closely with both external experts and potential end-users in identifying and pursuing priority technologies. Advisory committees and workshops have proved particularly useful since they provide the opportunity for intensive discussion and consideration of relevant issues. For example, before pursuing a program on structural control research, an area with significant potential for reducing the impacts of earthquakes on the built environment, NSF organized a structural control advisory committee comprised of prominent leaders in the field, including both researchers and potential users. This committee has played a major role in providing guidance on our program on structural control research which is now in its third year, including ways to exchange information with similar efforts worldwide.

A June, 1993 NSF-sponsored workshop on Directions for Research in the Next Decade is an example of how workshops are used to help set agency research agendas and to prioritize the development of technologies in the earthquake field. Researchers and practitioners were assembled in Washington D.C. for two days to discuss ways to enhance the participation of NSF in NEHRP; to discuss past accomplishments of NSF-funded research in the fields of earth science, earthquake engineering, and social science; and research needs in these areas in the next decade. The workshop recommendations are used by NSF and the other NEHRP agencies to prioritize future activities related to such topics as plate tectonics, fault mechanics, and ground response; the next generation of building codes; techniques for the rehabilitation and repair of existing buildings; and disaster planning and management.

The proposal peer review process used by NSF, as well as by USGS in its external research program, also helps to establish NEHRP priorities for future earthquake technologies. In the case of NSF, whether through mail review or panel review, reviewers are requested to comment on the relative significance of research proposals they evaluate. Such recommendations have a major influence on the projects that are subsequently funded to develop more effective earthquake hazard reduction technologies.

*Question.* The President's fiscal year (FY) 1995 budget of $103.2 million for the earthquake program requests a $3.6 million increase over this year's spending levels. H.R. 3485, passed last year, authorizes the program at $102.7 million for FY 1995 or $3.1 million increase. For a difference of $500,000 between the President's request and the House-passed bill, what agencies and activities will be affected?

Answer. H.R. 3485 authorizes $28.9 million for NSF's earthquake research programs in FY 1995. This is $1.8 million more than the amount included for these programs in the President's FY 1995 Budget Request. Thus, if FY 1995 budget is enacted as requested, NSF should be able to fully support its planned activities.

*Question.* H.R. 3485 contains several "Buy American" requirements which were not provided in previous earthquake program reauthorizations. Will any of these provisions change the way the Federal agencies undertake their work in the earthquake program?

Answer. No effect on NSF activities is anticipated.

*Question.* Electrical, gas, and water lines and communications are critical to battle secondary effects of earthquakes such as fire. What technologies have been developed under the earthquake program to protect these community lifelines1 from earthquake damage?

Answer. Through the NSF-funded National Center for Earthquake Engineering Research at the State University of New York, Buffalo, and at Princeton University and Cornell University, an advanced computer simulation capability—for water, gas, and electric power—has been developed and tested in the Memphis, Tennessee area and also used in San Francisco. The technology uses network analysis and theory to determine urban lifelines system behavior under earthquake scenarios and predicts service losses, such as loss of water pressure (which is important for fire fighting) and power outages.

This capability makes it possible for local governments and utilities to mitigate and prepare for problems caused by earthquakes. The results of computer modeling carried out in San Francisco by Cornell University researchers led to an upgrading of the city's water system and enabled the fire department to more effectively fight fires following the 1989 Loma Prieta earthquake.

NEHRP research has also resulted in the development of structural control technologies for modifying the response of lifeline systems to earthquake motions. For example, base isolation technology has been employed on some bridges in California to increase their capacity to withstand earthquake forces. While more experience with sizable earthquakes is needed before we can understand the full implications of such efforts, thus far this technology appears very promising.

*Question.* Research facilities help researchers to study the effects of earthquakes through simulations. How valuable are research tools like computer modelling and shake tables to NSF's research in the earthquake program?

Answer. These are research tools that are fundamental to advances in earthquake hazard mitigation. Large shake tables, such as those at the University of California, Berkeley, and the National Center for Earthquake Engineering Research, Buffalo, provide experimental data on the response of structures to simulated earthquakes—data which is very hard to measure in strong earthquakes, which by their nature occur at unexpected times and in unexpected places. Shake tables on geotechnical centrifuges provide data on the response of full scale structures, such as an earth dam, to simulated earthquakes. Computer modeling is now an intrinsic part of most research projects. It can vary from quite simple models to sophisticated models of complex systems such as a detailed model of a tall building and its foundation subjected to a given earthquake motion. Models are currently being developed for the response of the Los Angeles Basin to the rupture of known faults in the region. Many models can be run on desktop computers, while others require the power of supercomputers, and others, such as the model of the Los Angeles Basin, are beyond the ability of current supercomputers. For the latter application, the use of massively parallel computers is being explored in the development of these models.

*Question.* The last comprehensive review of earthquake research facilities in the U.S. was done in the mid-1980's. Is it time to study this issue again? What are the possibilities of using the research facilities of other countries, like Japan, to study earthquakes?

Answer. The Northridge earthquake reminds us that it is timely and important to revisit the question about the status and adequacy of experimental research facilities in the U.S. From the standpoint of both hazard reduction in this country and our ability to compete in international markets, it is important for the U.S. to have state-of-the-art experimental facilities. Under NEHRP, NSF has a principal role in supporting university research facilities. In cooperation with NIST and its other NEHRP partners, NSF is prepared to examine the status of experimental research facilities in the U.S. and has already entered into a dialog with them and other interested parties, such as academic experimental researchers and design engineers, about this matter.

There has been some limited use of foreign earthquake research facilities by U.S. investigators. However, this is a complicated matter because it is often difficult to get scheduled into a foreign facility and it can be very expensive. If resources are available, it could be argued that it is better to improve domestic facilities and to enter into cooperative research projects with foreign countries like Japan on the

basis of mutual interest and the availability of comparable resources, including research facilities.

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QUESTIONS ASKED BY SENATOR PRESSLER AND ANSWERS THERETO BY MR. MOORE

*Question 1.* In my statement, I mentioned that the cost of natural disasters concerns me. The major goals of this program should be aimed at saving lives *and* saving tax dollars. Much could be done to achieve these objectives if people simply had the information necessary to help them avoid living in dangerous earthquake prone areas.

*Question 1(a).* To what degree can the National Earthquake Hazards Reduction Program accurately identify such areas?

Answer. Under NEHRP, USGS has principal responsibility for identifying earthquake hazards, and this includes mapping. NEHRP has produced national scale maps which reflect the current state of knowledge about the sources of earthquakes in the U.S. Mapping of related earthquake hazards, such as liquefaction and landslide potential areas, has also been done at a regional scale. Generally speaking, more specific earthquake hazard identification data for earthquakes is known in the Western U.S. than in the Central and Eastern U.S. The most detailed information about earthquake hazards (on a State, local or individual scale) is available in California.

Your preface to this question suggests an interest in the larger scale of mapping, i.e., a more detailed mapping of hazards on a "people-scale". Soil-conditions at a building's site are important for the identification of such site-specific seismic hazards. NEHRP can provide or direct people to the technology for conducting site-specific seismic hazard analysis, but NEHRP does not provide that analysis for communities or individuals on an ongoing basis.

*Question 1(b).* Are state and local governments using this data to perfect building codes and/or zoning ordinances?

Answer. In the arena of zoning ordinances, or land use planning, some do. The use of it, however, is generally voluntary although there are some States (and local) jurisdictions where enacted laws require community development planning (e.g., California and Washington).

With respect to building codes, nearly all States or local governments which utilize building codes adopt one of the three major model building codes (i.e., Uniform Building Code, National Building Code or Standard Building Code). The groups which promulgate these codes have procedures for the incorporation of improved knowledge about earthquake hazards into their standards.

In addition, the *NEHRP Recommended Provisions for New Buildings* includes maps as appendices. This seismic design and construction resource is issued by the Building Seismic Safety Council (BSSC) which operates under the National Institute of Building Sciences. FEMA funds the continuing BSSC work and their updating of the *Provisions* in order to be able to establish national consensus on seismic design and construction. Thus, improvements in earthquake hazard identification can be reflected in this NEHRP issued resource material and be nationally applied. The relationship between the BSSC materials and that of the model code groups is excellent, and as of 1992, each of the model codes are substantially equivalent with the *NEHRP Provisions.*

*Question 1(c).* What role do you think Congress can play to help facilitate mitigation add move people from potentially hazardous areas?

Answer. NEHRP has learned a lot over the years about the impediments to mitigation adoption and the means to overcome these impediments. The most important lesson we have learned is that seismic mitigation policy adoption and enforcement will be implemented most comprehensively if the mitigation delivery system provides incentives.

In developing our National Mitigation Strategy we are trying to identify those incentives which can be reasonably offered to jurisdictions and individuals, in connection with existing, or feasible federal policies on buildings' and communities' resistance to disasters. We would be very pleased to work with your staff in defining how these and other elements of the strategy can be incorporated into your work and into that of the Congress.

*Question 2.* It has been recommended that perhaps it is time to reevaluate and restructure NEHRP to make it more effective. Would you agree that a comprehensive review of current earthquake programs is needed and, if so, what areas should such a review address?

Answer. Many reviews of NEHRP have been conducted, including reviews conducted by the General Accounting Office (1983), the Expert Review Committee

(1988), and the NEHRP Advisory Committee (1993). We believe these have sufficiently identified the issues and problems which should be addressed in order to improve the NEHRP management and accelerate the Program's effective implementation of earthquake risk reduction policies.

The Office of Science and Technology Policy, in response to a request from several members of Congress, has initiated an Executive Branch review of NEHRP. FEMA is supporting and cooperating in their work. OSTP does have the capability in consequence of this review to offer genuine suggestions that implement the findings of the NEHRP Advisory Committee, and others mentioned above. The OSTP report back to the Congress is expected in late 1994.

*Question 3.* As with any interagency program, poor coordination between bureaucracies often can seriously dilute the mission of an interagency group. Unfortunately, past hearings have revealed that the quality of this program's work has suffered at times for this very reason.

*Question 3(a).* How have you addressed this problem in the wake of the recent Northridge, California, earthquake?

Answer. Our belief is that each of the NEHRP Agencies has always worked reasonably well with one another, and that, in fact, NEHRP is one of the best *coordinated* programs in the federal sector. Each has been willing to provide the human resources for the conduct of interagency meetings and the like, and has been proactive in identifying opportunities for cooperative activities. In addition, the staffs of each of the Agencies have continuous contacts with one another, thus increasing the cooperative aspect of this multiagency program. The aspect which past hearings and past reviews of NEHRP have revealed is that the programmatic construct inhibits a comprehensive degree of *integrated* activities and the setting of cross-cutting priorities.

Several hours after the Northridge earthquake, the NEHRP Agencies began meeting in order to coordinate on identifying the investigatory opportunities presented by the earthquake, and the supporting role the Program should provide to the recovery effort. This resulted in an extremely well-coordinated plan of investigation and support. I am enclosing a copy of it for your information. We were able to employ this plan in using the $15M supplemental which the Congress appropriated to FEMA for the conduct of NEHRP investigations by the Agencies.

The following points will help explain the format of the "plan" for utilization of the NEHRP Supplemental appropriation:

- There are 4 major categories of activities discussed in the document under which NEHRP Agencies deal with the Northridge earthquake: 1) assisting response and recovery efforts; 2) learning the lessons of the event; 3) communicating those lessons and 4) applying those lessons. Most of the Supplemental funds are being spent on #2, or in other words, post-earthquake investigations. This conforms with the wording of the supplemental appropriation enacted by Congress and the language offered on the floor in support of it;
- After each task or project, there is noted either an Agency (or Agencies) or the phrase "NEHRP Program announcement" in parenthesis.

a) Where an Agency name appears, it indicates that a task or project will be carried out by the agency cited. In most cases, particularly with respect to the tasks and projects under II, the actions will be accomplished with the supplemental funds. In a few cases, Agencies will accomplish the task under normal NEHRP operating budgets;

b) Where the term "NEHRP Program announcement" appears, it indicates that funds were transferred to NSF for external, competitive grants. NSF agreed to administer this process for NEHRP.

- The NEHRP Agencies reached an agreement on the relative levels of balance to be achieved in 3 main areas of investigation: Hazard Environment; Built Environment; and Societal Environment. To summarize, these levels show built environment research to have the highest amount of support, hazard environment next, and societal environment third.
- The actual apportionment of the $15 million among the 4 Agencies was as follows: FEMA, $2.5M; NIST, $1.5M ; USGS, $4M; and $7M to NSF for the external grants.

THE NORTHRIDGE CALIFORNIA EARTHQUAKE—STRATEGY FOR THE UTILIZATION OF THE EMERGENCY SUPPLEMENTAL APPROPRIATION TO THE NEHRP AGENCIES

*Introduction*

In section 11 "Postearthquake Investigations Program," of the Earthquake Hazards Reduction Act, as amended, the four agencies that participate in the National Earthquake Hazards Reduction Program (NEHRP) are instructed to carry out a

postearthquake investigations program "so as to learn lessons which can be applied to reduce the loss of lives and property in future earthquakes." Specifically, Sec. 11 states that the Program Agencies—the Federal Emergency Management Agency (FEMA), National Science Foundation (NSF), National Institute of Standards and Technology (NIST), and United States Geological Survey (USGS)—shall jointly carrying out investigations of the implications of the earthquake in the areas of responsibility of each agency. The investigations should be done as rapidly as possible and results disseminated widely. The USGS is charged with the responsibility of organizing these investigations and each agency is given specific roles according to that agency's mission and expertise.

The Northridge earthquake of January 17, 1994, had serious impact to southern California and to the Nation. The loss of over 50 lives and billions of dollars of damage to the built environment in the San Fernando valley and adjacent Los Angeles metropolitan area from a magnitude 6.7 earthquake in one of the best earthquake prepared regions of the U.S. points to the continuing risk our Nation faces from earthquakes. In the Report to accompany H.R. 3759 which makes available a $15 million emergency supplemental appropriation to FEMA the intent of the appropriation is specified to increase the scientific understanding of earthquakes and to assess and make recommendations for improving upon seismic safety throughout the nation based on lessons learned from this disaster.

*Purpose and Objectives*

This document is intended to lay out a strategy by which the four NEHRP agencies will utilize the $15 million supplemental appropriation to accomplish the post-Northridge earthquake investigations in a timely and comprehensive manner. The NEHRP agencies are in agreement that there are four principal objectives to be addressed. First, the capabilities of the four agencies should be immediately applied to assisting local, state and federal jurisdictions carry out the recovery, reconstruction and mitigation processes in the aftermath of this earthquake. Concurrently, the four agencies should be taking steps to investigate the events associated with this earthquake, from the source of the energy, transmission of that energy through the earth, to its input into the built environment, and ultimately the resultant economic and social impacts and response. This may be described as learning the lessons of the Northridge earthquake. As those lessons are learned, the third objective of the NEHRP agencies is to collaborate in communicating those lessons that we are learning by whatever means are available and effective. Finally, in addition to communicating those lessons, the four agencies should take steps to see that those lessons are applied, both in southern California and, where appropriate to the rest of the United States.

## I. ASSISTING RECOVERY, RECONSTRUCTION AND MITIGATION

*The Problem*

The majority of the immediate recovery and reconstruction needs are being met through other provisions of the Dire Emergency Supplemental. The purpose of this objective of the NEHRP effort is to provide information and lessons learned from past earthquakes, as well as the Northridge earthquake, regarding the continuing hazard environment of the region and the risk to the built environment. This information should be provided in proactive ways to guide and influence the overall process of quickly and safely restoring the disrupted community to normal operations, and improve the mitigation provisions for the damaged built environment. There will be immediate and long-term demands from Federal, State, and local government agencies requesting information on the standards, guidelines, and practices to be used in the reconstruction and repair of buildings, critical facilities and lifelines; the NEHRP agencies must be prepared to address those demands.

*Tasks*

1. The NEHRP agencies will serve as a technical resource for input to a recovery and reconstruction decisions that will be underwritten by the Federal government. [All NEHRP agencies]
2. Develop a GIS-based risk map that will incorporate general levels of ground shaking, local site amplification, and potential ground failure, that will be used in reconstruction. [NSF, FEMA, USGS]
3. Disseminate in a timely manner results of investigations conducted as described in the next section that can contribute to the recovery and reconstruction efforts. [All NEHRP agencies]
4. Provide to the engineering community information on current state-of-art techniques for the repair of damaged structures through public meetings and workshops

bringing together the researchers, practitioners and the standard setting organizations. [NSF, FEMA, NIST]

II. LEARNING THE LESSONS OF THE NORTHRIDGE EARTHQUAKE

*A. The Hazard Environment*

*The Problem*

The tragic effects of the Northridge earthquake over a broad region of the San Fernando and Los Angeles basins, and surrounding mountains have graphically demonstrated the hazard that southern California faces from buried faults underlying the sedimentary basins. The Northridge earthquake focused the concern of the earth science community on better defining the hazard associated with these buried faults and how the earthquake energy, once released, is transmitted and amplified through the sedimentary basin. This hazard is not unique to southern California; several large metropolitan areas of the U.S. are situated on sedimentary basins that are bordered by, contain, or are underlined by active faults. Although the magnitude of the earthquakes from these buried faults may not be as large as those which can be expected from nearby surface faults such as the San Andreas and San Jacinto, the failure plane dipping under much of the populated region can result in the wide destruction and casualty patterns seen in Northridge. In addition, the sedimentary basin itself demonstrated a tendency to distribute, focus, and amplify the earthquake energy to a much larger degree than previously expected.

*Tasks*

*Assessing the Earthquake Source.*—1. Support the immediate seismological, geodetic and geological field work to collect data from the Northridge earthquake. Understanding the scientific aspects of the earthquake, so that the lessons learned can be applied to future earthquakes, requires careful and systematic collection of perishable seismological and geological data in the weeks and months following the earthquake. Also, the quantity and complexity of the data is overwhelming current data storage, so that the archive facilities need to be expanded and improved [NSF-SCEC, USGS]

2. Conduct a systematic, quantitative inventory of damage in a geographic framework that provides a modern assessment of the Mercalli Intensity Scale and its reliability for public use. The investigation will also compare and contrast the damage patterns that resulted from the San Fernando earthquake of 1971 (magnitude 6.7) and the Northridge earthquake of 1994 (magnitude 6.7). [USGS]

3. Undertake extensive geophysical and geological investigations that will elucidate the regional fault structures and accelerate the understanding of potential earthquake hazards. The Northridge earthquake occurred on a hidden faults that did not rupture to the surface of the earth (blind thrust fault). Similar faults underlay the Los Angeles and Ventura basins. [NEHRP Program Announcement and USGS]

4. Study the details of the Northridge rupture process, with emphasis on the factors that contributed to the severe ground motions that were recorded on many strong-motion instruments throughout the San Fernando Valley and Los Angeles Basin [NEHRP Program Announcement and USGS]

5. Clarify the different contributions of the earthquake source from the site and path effects in the strong-motion records of the mainshock, using recordings of aftershocks from the same sites. [NEHRP Program Announcement and USGS]

6. Collect and analyze geological and geophysical data that will provide insight into the recurrence of earthquakes in the San Fernando valley with the intent of forecasting the future hazard for the region, and determining estimates of the levels of ground shaking that the valley will experience in future earthquakes. [NEHRP Program Announcement and USGS]

7. Analyze the three-dimensional physical character of the San Fernando Valley and monitor how the valley gradually changes in geometry over the coming months and years using geodetic surveys including GPS. [NEHRP Program Announcement and USGS]

8. Improve broadband and strong-motion seismic instrumentation to record the continuing aftershocks from Northridge. Seismic source parameters derived from these data will clarify the source processes of the Northridge earthquake and larger aftershocks. [USGS]

*Assessing the Influence of Geological Structures.*—1. Conduct a systematic study of how the San Fernando sedimentary basin caused local amplified shaking and focusing of energy which was a direct cause of a substantial amount of the building damage from the earthquake and how this can be applied to assessing the hazard in the Los Angeles basin. [NEHRP Program Announcement and USGS]

2. Undertake detailed active and passive seismic experiments to image the basin structures of the San Fernando Valley, Los Angeles, and San Bernardino areas. Detailed information about the basins structure will enable better modeling of ground motions from damaging earthquakes. [NEHRP Program Announcement and USGS]

3. Study the local site effects of seismic waves on a block by block scale in the heavily damaged area of Northridge. Correlate the seismological results with the damage surveys. Determine the variability of the shaking within short distances of less than 1 km. [NEHRP Program Announcement and USGS]

4. Categorize local site response by shallow shear-wave velocity measurements and correlate with amplitudes of strong ground motions. [NEHRP Program Announcement and USGS]

5. Study and characterize nonlinear amplification of ground motions on soft rock and soil sites. [NEHRP Program Announcement and USGS]

6. Investigate the causes of the sustained and high amplitude shaking of over 1 g that was recorded in Tarzana, at a relatively large distance from the earthquake. [NEHRP Program Announcement and USGS]

7. Examine the local site response effects that may have amplified seismic waves and caused damage at the collapsed freeway sites (I5-highway 14 interchange, highway 118 near Woodley, I10 at La Cienega). [NEHRP Program Announcement and USGS]

8. Evaluate the role that ground failure played in disruption of lifelines, particularly lateral spreading and liquefaction, and apply the knowledge acquired from this earthquake to prepare new ground failure risk maps. [NEHRP Program Announcement and USGS]

*Combining Earth Science Information into Products.*—1. Produce realistic time histories of ground motions from scenario earthquakes in populated areas. [NEHRP Program Announcement and USGS]

2. Produce local site response maps that show variations of expected ground motions. [NEHRP Program Announcement and USGS]

3. Produce regional seismic hazard maps using both deterministic and probabilistic methods of earthquake occurrences. [NEHRP Program Announcement and USGS].

*B. The Built Environment*

*The Problem*

The damage to the built environment due to the Northridge earthquake has been widespread and varied. The earthquake has damaged thousands of buildings and structures of different types—bridges, hospitals and essential service buildings, apartment buildings, parking structures, power systems including substations and transmission lines, communication systems, water and gas distribution systems, old as well as more recently constructed buildings, and many more. The urban infrastructure system in the region has especially suffered severe damage, causing loss of life, serious economic losses and prolonged disruptions of essential services. The preliminary data indicates that structures were subjected to large components of vertical motion in this earthquake; this uncommon observation has important engineering design implications requiring further investigation. In the light of the San Fernando earthquake in the same region in 1971 and subsequent upgrading of building codes, the studies on the performance of various upgraded structures in this earthquake are of particular importance. This event provides very valuable data to study the performance (both failures and successes) of our civil infrastructure and other built environment exposed to strong ground shaking with the primary objective of recommending improved engineering design methods to avoid future failures, and to develop better operating, monitoring and management procedures to avoid serious disruptions. The required studies are divided into the following areas, although studies cutting across these topics may also be necessary.

*Tasks*

*Siting and Geotechnical Engineering.*—1. Conduct coordinated geologic, geophysical and geotechnical investigations to determine the ground shaking and permanent ground deformation that occurred beneath failed freeway structures and the gas and water pipelines. [NEHRP Program Announcement and USGS]

2. Determine the variation in the level of ground shaking (including acceleration, velocity, displacement and spectral content) in terms of source, propagation path and site affects. Investigate the use of the currently available linear or nonlinear analysis techniques to explain and predict the observed information. [NEHRP Program Announcement and USGS]

3. Examine the performance of concrete, earth and rock-fill dams, including the performance of abutments and foundations, especially of those dams that suffered

significant failures in the 1971 San Fernando earthquake. [NEHRP Program Announcement]

4. Evaluate the performance of earth slopes and earth retaining structures; compare observed and predicted behaviors; evaluate the validity of design assumptions and approaches and their implications concerning existing codes. Study the role of earthquakes in landsliding. [NEHRP Program Announcement, USGS]

5. Study the use of the liquefaction and ground displacement data to validate the methods for predicting the residual strength of liquefied sediments and also to validate the methods used for predicting liquefaction phenomenon itself; examine the effect of mixing constituent particles, e.g., sand with silt etc. [USGS, NEHRP Program Announcement]

6. Study the level of performance with the intensity of shaking of sites where ground improvement techniques were used. [NEHRP Program Announcement, USGS]

7. Examine the influence of dry fills on ground deformations and structural damage, especially on water and gas pipelines located at a distance from the epicenter. [NEHRP Program Announcement]

8. Study of ground motion characteristics of solid waste landfill sites in the epicentral region and back-calculate the strength of the fill and cap material to compare with design assumptions. [NEHRP Program Announcement]

9. An investigation that will compare how measured ground surface motions contributed to the motion of buildings; major focus will be structures built in the past two decades since the UBC upgrade in 1975. [USGS]

*Buildings and Structures.*—1. Study of damaged reinforced and unreinforced masonry structures: The masonry structures are very vulnerable to ground shaking and the Los Angeles area has a large inventory of them. There was widespread damage to these structures in this earthquake. It is important to study these damage patterns and recommend ways to retrofit them. From the damage data, the effectiveness of existing retrofitting and strengthening techniques as well as the effects of city's existing seismic ordinance need further examination. [NEHRP Program Announcement]

2. Study of concrete structures—performance evaluation and validation of current design procedures for ductile and nonductile RC frame structures; RC slab-column systems; waffle slab systems; RC shear wall systems. Comparison and contrast studies of the performance of these structures in this and in the 1971 San Fernando earthquakes. [NEHRP Program Announcement]

3. Study of steel structures—performance evaluation of steel structures including moment resistant frames, connections (bolted and welded) and members to recommend better design methods. Evaluation of the performance of composite constructions made of concrete and steel. [NEHRP Program Announcement]

4. Examination of some cases of poor performance of structures designed according to codes updated after the 1971 San Fernando earthquake. [NEHRP Program Announcement]

5. Study of the performance of buildings retrofitted and/or repaired after 1971 earthquake. Correlation of the extent of retrofit and the level of damage in buildings. [NEHRP Program Announcement]

6. Study of the base-isolated buildings in the affected area which are well instrumented. This earthquake has provided excellent data for performance evaluation of the base isolated buildings and also for evaluating the concept of base isolation as a viable rehabilitation and vibration mitigation strategy. [NEHRP Program Announcement]

7. Investigation of the performance of structures which have protective systems such as energy absorption devices, dampers, active and hybrid control techniques as cost effective mechanisms to reduce loss and damage. [NEHRP Program Announcement]

8. Studies on the dynamic behavior and performance of instrumented buildings. A comprehensive analysis of the recorded response data will enhance our understanding of the dynamic behavior of building structures for their better design in future. [NEHRP Program Announcement, USGS]

9. Study of precast and/or prestressed concrete structures (including parking structures) which suffered substantial damage in this earthquake. Study of the tilt-up constructions and precast diaphragms in buildings. [NEHRP Program Announcement]

10. Study of the effect of strong vertical component on structural performance. [NEHRP Program Announcement]

11. Examination of the performance of nonstructural and architectural components vis-a-vis the recent incorporation of the design provisions in the building codes. [NEHRP Program Announcement, NIST]

12. Performance evaluation of low-end engineered construction such as two and three story apartment buildings and recommendations for their economical retrofits. [NEHRP Program Announcement]

13. Conduct a review and revise guidelines for vulnerability assessment and rehabilitation of existing buildings based on observed performance in this earthquake. [NEHRP Program Announcement, NIST]

*Urban Infrastructure Systems—Lifelines.*—Transportation Systems.—1. Study of highway bridge systems; dynamics and performance of curved, continuous and balanced cantilever bridge and column support systems; expansion joints and pounding; size of bearing seats; evaluation of cable restraints; bridge-abutment and backfill interaction; shear deformation in large box girder bridges decks; evaluation of the spatial variation of ground motion on bridge motions; effect of vertical components; local site and topology effects; performance of column bent supports. [NEHRP Program Announcement]

2. Evaluation of bridge column retrofit schemes—steel jackets, fiber reinforcements, energy absorption, isolation and active control devices. Study on the uses of light and high strength modern composite materials for economical and swift on-site replacement of damaged decks. [NEHRP Program Announcement]

3. Evaluations of current bridge design codes vis-a-vis the observed performance of the bridges designed according to them; development of performance-based design codes; collocation failures of different but interacting links of different systems. [NEHRP Program Announcement]

4. Studies on the comparison and contrasts of the performance of bridges in the 1971 San Fernando and 1994 Northridge earthquakes. [NEHRP Program Announcement]

5. Study of the post earthquake performance of the transportation system in the affected area; effectiveness of smart corridors, alternative routing and performance near damaged nodes; post earthquake traffic pattern and its management. [NEHRP Program Announcement]

Communication and Power Systems.—6. Performance evaluation of power transmission and distribution systems; structural failures of transmission towers and foundations; structural failures in retrofitted Sylmar substation; performance of porcelain insulators. [NEHRP Program Announcement, NIST]

7. Performance study of communication systems and their critical nodes; interaction of power and communication systems and emergency management systems. [NEED Program Announcement]

8. Examination of data processing, storage and transmission systems; effectiveness of base isolation devices of sensitive data storage and processing systems. [NEHRP Program Announcement]

Pipelines: Water and Gas Distribution Systems.—9. Performance evaluation of water treatment facilities; performance of wooden baffles and sludge scrapers; water sloshing effects; recommendations for improved performance. [NEHRP Program Announcement]

10. Study of the interaction of buried pipes and pipe joints with surrounding media; effect of spatial variation of ground motion and its prediction; GIS-based seismic vulnerability and performance studies; gas leak monitoring and control studies; fire prevention studies. [NEHRP Program Announcement, USGS]

Risk and Damage Assessments.—1. Interim short-term USGS/FEMA collaborative study to provide data in support of the on-going National Institute of Building Sciences study to develop a standardized loss estimation methodology and support efforts that will lead to a modern, reliable Intensity Scale for public use. [FEMA, USGS]

2. Determine how the effects of this earthquake on the built environment have an influence on the spectral response and other risk maps for this region, for California in general, are for the national risk maps. [FEMA, USGS]

3. Investigations to compare and contrast the damage patterns and vulnerability that resulted from the San Fernando earthquake of 1971 and the Northridge earthquake to determine the effectiveness of NEHRP risk mitigation activities over the past two decades. [FEMA, USGS, NEHRP Program Announcement]

4. Determine rational values for response modification factor and design coefficient factors in the seismic provisions based upon the new observations from this earthquake. [NEHRP Program Announcement]

5. Study the cause of fire and its spread in this earthquake, and recommend loss reduction practices. [NEHRP Program Announcement, NIST]

*C. Socioeconomic Impacts and Social Response*

*The Problem*

To further mitigation and preparedness planning throughout the nation, it is important to learn how people are directly and indirectly affected by events like the Northridge earthquake. Such knowledge can increase awareness and inform decisions regarding acceptable risk, function as a catalyst for heightened hazard reduction efforts by individuals, groups, and organizations and serve as the basis for improving earthquake education and dissemination programs.

Important insights can also be gained for advancing mitigation and preparedness efforts in the nation by investigating the state of readiness and the pattern of group, organizational and institutional response to both the short- and long-term problems presented by the Northridge earthquake. Careful study and analysis of how organizational and institutional systems responded to the postearthquake environment should provide generic lessons that can serve as a basis for improving society's response to future earthquakes.

*Tasks*

1. Investigation of the immediate and long-term social and economic impacts of the earthquake, including those caused by disruptions to the civil infrastructure. [NEHRP Program Announcement]
2. Comparison of the socioeconomic impacts of the 1971 and 1994 earthquakes. [NEHRP Program Announcement]
3. Analysis of the causes of casualties, including the role of the performance of structures, their nonstructural components, and the behavior of individuals. [NEHRP Program Announcement]
4. Investigation of emergency response efforts, including those related to search and rescue and the provision of shelter, fire, police, public works, and medical services. [NEHRP Program Announcement]
5. Evaluation of the communication of risk information, including by the scientific community, public officials, and the media. [NEHRP Program Announcement]
6. Analysis of damage assessment and decision making regarding the disposition, including demolition of damaged structures. [NEHRP Program Announcement]
7. Analysis of individual, business, and community recovery, including the role of earthquake insurance in recovery and reconstruction. [NEHRP Program Announcement]
8. Analysis of the progress made by the region in mitigation and preparedness between the 1971 and 1994 earthquakes. [FEMA, NEHRP Program Announcement]
9. An econometric model applied to predicting expected future losses from earthquakes in the San Fernando and Los Angeles basins and a cost-benefit analysis and cost-effectiveness analysis of the Alquist-Priolo Act will be applied to the affected region. [USGS]
10. Establish a consistent methodology by which the direct and indirect costs resultant from the earthquake damage can be estimated. [FEMA]
11. An analysis of the economics of this earthquake in terms of how the earthquake may have helped stimulate the local community, what other resources are involved in recovery in addition to Federal disaster assistance and insurance, and recommend improvements to future Federal assistance programs. [FEMA]
12. Assess the impact of the earthquake on the environment, including disposal of large quantities of rubble, release of toxic materials, impact on solid and liquid waste facilities, all of which impact the social and economic well being of the region. [FEMA]
13. Study costs and benefits of structural and nonstructural mitigation retrofits. Focus on successful mitigation retrofits. [FEMA]
14. Study factors that influence homeowners and property owners to implement mitigation actions prior to a disaster and what incentives would encourage those actions. [FEMA]
15. Evaluate contributions of preexisting recovery plans to the mitigation effort at Northridge and other disasters. [FEMA]

III. COMMUNICATING THE LESSONS LEARNED FROM THE NORTHRIDGE EARTHQUAKE

*The Problem*

Through the cooperation of researchers, practitioners, government officials, professional associations, and others, much will be learned about the Northridge earthquake. Since the earthquake, significant efforts have been underway to collect and analyze perishable information, and it is anticipated that activities resulting from this announced program will produce substantial new knowledge useful for advancing the state of mitigation and preparedness throughout the nation. The successful

application of this new knowledge base, however, requires major proactive efforts by many groups. Existing channels of communication between investigators and practitioners will be utilized, but new channels and innovative approaches could also contribute to making results from the postearthquake investigations widely available to those responsible for evaluating earthquake risks, improving the design of buildings and infrastructure systems, determining the location of critical structures, and advancing preparedness efforts in vulnerable regions of the United States.

*Tasks*

1. Similar to the postearthquake investigation program sponsored by NEHRP after the 1989 Loma Prieta earthquake, investigators funded under this announcement will be expected to contribute to a comprehensive NEHRP report on the Northridge earthquake that will detail the important geological, geophysical, engineering, and social, and economic aspects of the event. They will also be encouraged to take advantage of opportunities to disseminate the results of their projects through other channels, especially those that are used by such practitioners as architects, engineers, planners, and emergency managers. [USGS]
2. In addition to the NEHRP report, the following types of activities by all NEHRP agencies will be considered to further the communication of lessons learned from the Northridge earthquake to relevant groups:
   - Collection, archiving, publication of research results and information on the earthquake.
   - Professional and public educational efforts to disseminate results.
   - Development, and utilization of model and innovative methods, such as Geographic Information Systems (GIS) to disseminate information to practitioners and decisionmakers.
   - Various seminars, workshops, symposia, and video tapes to convey lessons learned to specific user groups.
3. Improve capability to disseminate information in a near real-time mode for broad distribution via telecommunications linkages to the other NEHRP agencies and various public entities. [USGS]
4. Research current methods of transferring geotechnical and earthquake engineering data to emergency management agencies. Include recommendations to improve information transfer methods. [FEMA]
5. Assess the need and impact of real-time seismic information for government agencies, utilities, and large businesses. [NEHRP Program Announcement]

APPLYING THE LESSONS OF THE NORTHRIDGE EARTHQUAKE TO ADVANCE MITIGATION

*The Problem*

To reap the full benefit of the lessons learned from this earthquake, the information must be incorporated into the activities on a National scale. Certain activities that had been initiated by NEHRP prior to this earthquake can be assessed in light of their impact during this event. In addition, new information and innovations that have arisen from this earthquake can have impact on other regions of the nation. It is important that these lessons and opportunities be fully exploited in the coming months.

*Tasks*

1. Connect the available levels of structural and nonstructural mitigation to applicable "triggers" which will greatly enhance the decision making capabilities of local and state jurisdictions; this study will catalogue and examine pre-Northridge triggers to determine cost-effectiveness, what new triggers have been effectively emplaced since the earthquake, and what additional triggers are recommended. [FEMA]
2. Examine what incentives for reduction of earthquake risk were available to state and local jurisdictions, and the private sector, before and subsequent to the earthquake, and determine what incentives are most effective and efficient. [FEMA, USGS]
3. Very little is known about the liability issues which may emerge after earthquakes; court records for representative cases will be reviewed to obtain a clearer understanding of the tort liability issues that would be present elsewhere in California and across the U.S. [FEMA]
4. Develop documents of use to other regions of the country regarding new insights into the specific hazards and resultant risk from buried faults and basin effects, e.g. Portland, Seattle, San Francisco, Anchorage. [USGS, FEMA]

AGREEMENT

By signature below, the Agencies of the Interagency Coordinating Committee of the National Earthquake Hazards Reduction Program agree to the following:

1) The preceding information represents the framework and tasks upon which the Agencies of the National Earthquake Hazards Reduction Program are basing their response to and investigation of the Northridge earthquake of January 17, 1994;

2) Agency responsibilities for specific tasks are reflected by the information in brackets after each task;

3) The term "NEHRP Program Announcement" means that the tasks will be included in a publicly announced, open grant competition, NEHRP request for proposals. The administration of these will be conducted by the National Science Foundation with collaboration from the NEHRP Agencies on the review and award of proposals, and with the technical monitoring of awarded grants by another NEHRP Agency when appropriate given the nature of its NEHRP responsibilities;

4) For those tasks which reflect a specific NEHRP Agency or Agencies, that Agency or Agencies agree to make every reasonable effort to accomplish the task within the context of its normal NEHRP operating budget, or within the context of the post-Northridge NEHRP supplemental funds; and

5) Under the interagency agreements which will be emplaced to transfer to each NEHRP Agency from FEMA any NEHRP supplemental funds, each Agency agrees to provide a progress report on each task on a semi-annual basis to FEMA, and a final report to FEMA within 24 months. FEMA will also prepare these same progress reports to share with the NEHRP Agencies.

ROBERT VOLLAND,
*FEMA.*
ROBERT WESSON,
*USGS.*
RICHARD WRIGHT,
*NIST.*
WILLIAM HAKALA,
*NSF.*

*Question 3(b).* How well did federal buildings withstand the effects of the Northridge earthquake?

Answer. In general, federal buildings behaved much the same as the population of buildings surrounding them: those designed and constructed to resist earthquakes and provide for life safety performed well. Each federal agency which owned buildings in the earthquake area (e.g., General Services Administration, Department of Energy, Veteran's Administration) conducted their own detailed analyses of the earthquake's impacts on their buildings.

*Question (c).* How closely does the NEHRP assess federal buildings for proper retrofitting and earthquake-resistant engineering?

Answer. Similar in context to the previous point, each federal agency addresses the assessment and proper retrofitting of its own buildings. However, the sharing of information and coordination of federal activities, with respect to the seismic safety of federal buildings, is carried out by the member Agencies of the Interagency Committee for Seismic Safety in Construction (ICSSC) under NEHRP. The ICSSC is chaired by the National Institute of Standards and Technology, one of the NEHRP Agencies. The Committee has adopted standards for the assessment and retrofit of existing buildings, and has recommended that these be formally endorsed by the President.

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